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BEARING METAL ALLOYS.*

BY C. B. DUDLEY, Ph.D.,
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[*Concluded from p. 93.*]

It will be observed that the method was to compare the relative loss of metal by wear of various alloys with a certain standard alloy. It should be stated that likewise observations were made on the behavior of the experimental alloys as to heating. No observations were made as to the difference in friction with the different alloys. This field is entirely unexplored, so far as I know. The first test was a comparison of the old copper-tin alloy with the standard phosphor-bronze bearing metal. The results obtained were as follows:

* Abstract of a lecture delivered before the Franklin Institute.

COPPER-TIN VS. PHOSPHOR-BRONZE.

	Composition Copper-tin Per Cent.	*Composition Phosphor-bronze. Per Cent.*
Copper,	87·50	79·70
Tin,	12·50	10·00
Lead,	none	9·50
Phosphorus,	none	0·80

Wear.—First experiment, copper-tin wore forty-eight per cent. faster than phosphor-bronze; second experiment, copper-tin wore fifty-three per cent. faster than phosphor-bronze; third experiment, copper-tin wore forty-seven per cent. faster than phosphor-bronze.

It should be stated that the analyses are approximately average analyses, rather than special analyses of the samples in each test, and it will be observed that there is no allowance for small impurities of zinc, iron, antimony, etc. It will be observed also that in expressing the loss of metal by wear, the loss is given in percentages of loss of metal compared with standard phosphor-bronze. It is entirely clear, we think, from the above experiments that the copper-tin alloy of seven to one, is nothing like as valuable as the standard phosphor-bronze for bearing metal, and this view is confirmed from knowing that the experiments above given were made on some hundred bearings of each kind, and that a much larger percentage of the copper-tin bearings heated than the phosphor-bronze. So satisfactory were these experiments that the phosphor-bronze bearing metal was for quite a long time used as the standard bearing metal for car bearings on the Pennsylvania Railroad. It was not deemed advisable to allow the matter to rest there, and accordingly experiments have constantly been in progress to secure modifications which would give better results. Just here I would like to call attention to a matter of importance. You will observe that the copper-tin bearing metal differs from the phosphor-bronze in several particulars. First, the phosphor-bronze has less tin; second, it has quite a percentage of lead, and third, it has some phosphorus. Please make a note of these points as they will be referred to later.

It is not intended to give the results of all the tests that have been made during the last fifteen years, but only such a selection from them, as will apparently illus-

trate a law, and show the development of our knowledge leading to present practice. Accordingly, the next experiment will be one which we think throws considerable light on the matter, namely, an experiment with arsenic-bronze. It has been found that arsenic practically takes the place of phosphorus in a copper-tin alloy. Accordingly, several experiments were made with arsenic-bronze. The results of these experiments are as follows:

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*First experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze.* Per Cent.
Copper,	89·20	79·70
Tin,	10·00	10·00
Lead,	none	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic-bronze wore forty-two per cent. faster than phosphor-bronze.

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*Second experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze.* Per Cent.
Copper,	79·20	79·70
Tin,	10·00	10·00
Lead,	7·00	9·50
Phosphorus,	none	0 80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore fifteen per cent. faster than phosphor-bronze.

ARSENIC-BRONZE VS. PHOSPHOR-BRONZE.

(*Third experiment.*)

	Composition Arsenic-bronze. Per Cent.	*Composition Phosphor-bronze.* Per Cent.
Copper,	79·70	79·70
Tin,	10·00	10·00
Lead,	9·50	9·50
Phosphorus,	none	0·80
Arsenic,	0·80	none

Wear.—Arsenic bronze wore one per cent. faster than phosphor-bronze.

It will be observed that the first experiment was practically a copper-tin alloy containing some arsenic, and that this wore very nearly as fast as the copper-tin alloy seven to one. I have been accustomed to regard this experiment as

indicating that the phosphorus in bearing metal alloys does not have very valuable influences on the wear, and as has already been hinted at in the earlier part of the lecture, the phosphorus seems to be more valuable in the foundry than in the service. The second experiment, it will be noted, differs from the first in introducing some lead in the alloy, and it is extremely interesting to note that although the arsenic and tin remain the same as in the first experiment, the introduction of the lead produces a diminution in the rate of wear which is very marked. After this experiment was concluded, a third experiment was tried in which the composition of the arsenic-bronze was patterned as near as possible after that of the phosphor-bronze, and it is interesting to note that in this case the wear of the two was almost the same. The heating of the arsenic-bronze alloys in service was no greater than the phosphor-bronze, and there were no other appreciable differences to be discovered in the behavior of the metal, except as the figures above show the rate of wear.

It is interesting to note that these experiments thus far made seem to indicate first, that the introduction of phosphorus or arsenic into a bearing metal has very little influence on the rate of wear, while the introduction of lead has a very marked influence on the rate of wear.

In view of these teachings, it was decided to extend still further the influence of lead on bearing metal. Accordingly, a bearing metal was obtained which contained still more lead than the standard phosphor-bronze. This metal we will call "K" bronze. The result of the experiment with "K" bronze is as follows:

"K" BRONZE VS. PHOSPHOR-BRONZE.

	Composition "K" bronze. *Per Cent.*	*Composition Phosphor-bronze.* *Per Cent.*
Copper,	77·00	79·70
Tin,	10·50	10·00
Lead,	12·50	9·50
Phosphorus,	none	0·80

Wear.—First experiment, "K" bronze wore eight per cent. slower than phosphor-bronze; second experiment, "K" bronze wore 7·30 per cent. slower than phosphor-bronze.

This experiment to my mind is extremely interesting. It should be said that no trouble was experienced from heating with the "K" bronze, more than with phosphor-bronze, and no other peculiarities, other than the rate of wear as given, were observable. There is no phosphorus in the "K" bronze; practically the same tin, and an increase in lead, and as the result of these changes, the "K" bronze, as will be observed, surpasses the phosphor-bronze in wear. It seems almost indisputable, that we are certainly on the right track in the matter of developing a bearing metal which will be satisfactory in every sense in service.

The value of lead in a copper-tin alloy for bearing metal, being apparently so well established, it became a question of how much lead could be gotten into the alloy without running into difficulty. Also about this time there began to be evidences of a law, governing the composition of all bearing metal alloys, which law may be briefly stated as follows:

"That alloy which has the greatest power of distortion without rupture, will give best results in wear." We will refer to this law, and show a possible broadening of it, into a more general law a little later, but at this time in accordance with this law, we started to design an alloy which would have as great power of distortion as possible without rupture. To do this we attacked the problem from two stand-points; first, the proportions of copper and tin, and then this having been established, the proportion of lead. Upon the first of these two points there are some very interesting data. It is common knowledge that an alloy of two parts copper to one of tin, which is usually called "speculum metal," is one of the most brittle substances known. I have a sample here, and you will observe that by simply dropping this piece, which is 2 inches wide, 3 inches long, by ¼ inch thick, upon the floor from the height of the table, it breaks into a large number of pieces. Also if I lay it on an anvil and take a hammer and strike it, it flies even worse than glass, and is readily pulverized. This speculum metal will suffer almost no distortion, therefore, without rupture. It can neither be bent nor distorted in

any way without breaking. If now the percentage is changed, and an alloy is made of three parts copper to one of tin, we get a substance which is less brittle. Four parts copper to one of tin, is still less brittle, and begins to be a metal which will suffer some distortion without rupture. Five parts copper to one of tin is common bell metal. Seven parts copper to one of tin is, as has already been described, the well-known cannon bronze, which has also been largely used as a bearing metal. The point that I want to make, and that seems clear to me, is that a metal can be made out of copper and tin, which will suffer more and more distortion without rupture, by diminishing the tin and increasing the copper. After experimenting somewhat in this line, we finally decided on a proportion of copper and tin, about nine and one-half parts copper to one of tin. We have some evidence, obtained since the experiments I am about to give you were made, that indicate that we could have gone still farther, and made the ratio of copper to tin, twelve or possibly fifteen copper to one of tin. This point has not yet been definitely proven. The ratio of copper to tin having been established, the question of how much lead to use came up, and as a consequence the question of the influence of lead on a copper-tin alloy arose. I do not think that this point has been fully worked out, but as far as we have gone, the indication seems to be, that the addition of lead has much the same influence on a copper-tin alloy, that a still further diminution of tin would have. That is to say, if an alloy of copper and tin is made, fifteen parts copper to one of tin, it will probably have much the same physical properties, and give much the same results in wear, as an alloy of ten parts copper to one of tin, which alloy contains quite a large percentage of lead. I say this point has not yet been fully worked out, but what indications we have point in this direction. It should be stated here, that as the amount of tin is diminished, and the amount of lead is increased, the tendency of the metal to yield more readily under pressure increases, so that it becomes essential to guard against possible dangers of having a metal which would yield too readily under the load. After

considerable preliminary work, bearings were cast, and a wearing test made, the results of which are as follows, the new metal being called alloy "B:"

ALLOY "B" VS. PHOSPHOR-BRONZE.

	Composition Alloy "B." Per Cent.	*Composition Phosphor-bronze.* Per Cent.
Copper,	77·90	79·70
Tin,	8·00	10·00
Lead,	15·00	9·50
Phosphorus,	none	0·80

PHYSICAL PROPERTIES.

	Alloy "B."	*Phosphor-bronze.*
Tensile strength, per square inch, pounds,	24,000	30,000
Elongation, per cent.,	11	6

Wear.—Experimental alloy "B" wore 13·50 per cent. slower than phosphor-bronze.

It will be observed that this alloy wears considerably better than the standard phosphor-bronze, and the best of any in the series; also, that it is lower in tin and higher in lead than the phosphor-bronze. It will also be observed that the physical properties of alloy "B" were taken in comparison with phosphor-bronze, and that the characteristics are that alloy "B" has a lower tensile strength, but a greater elongation than the phosphor-bronze. It is well known that the elongation measures to a greater or less extent, the capacity of the metal to suffer distortion without rupture. Those metals which can be tied in a knot, so to speak, have the greatest elongation, when subjected to the ordinary physical test of pulling until rupture takes place. The alloy "B" above given, with a slight modification which enables the Pennsylvania Railroad to use the large amount of phosphor-bronze scrap that it has, is the standard bearing metal of that road, and is regarded as the best that is now known on the subject of bearing metal alloys. It is not at all certain, however, that a still further modification in the diminution of tin and increase of lead, would not give even better results. Some experiments have been made toward still further diminishing the tin, and increasing the lead, but it is found that a certain amount of tin is neces-

sary to hold the lead alloyed with the copper, and apparently the limit of the diminution of tin and increase of lead is not a great ways from the composition of alloy "B." Of course, it will be agreed that when the lead will not stay alloyed long enough to allow successful castings to be made, the limit of diminution of tin and increase of lead has been reached, and there are some indications as stated above that the analysis above given is not a great ways from the limit.

The formula used on the Pennsylvania Railroad in making the standard bearings patterned after alloy "B" is as follows:

	Pounds.
Copper,	105
Phosphor-bronze, new or scrap,	60
Tin,	9¾
Lead,	25¼

By using ordinary care in the foundry, keeping the metal fairly well covered with charcoal during the melting, it is entirely possible to get perfectly successful castings in car bearings on the above formula. The copper and the phosphor-bronze can be put in the pot all at once before putting in the melting hole. The tin and lead should be added after the pot is taken from the fire. This formula gives approximately the analysis under the heading Ex. B Metal, mentioned in the earlier part of this lecture.

It is of course a fair question whether the introduction of a little zinc, or possibly some other combinations of the six or eight metals commonly used for alloys, will not give a bearing metal much better than the alloy "B." All that I can say on this point is that alloy "B" represents the best knowledge that we have on the subject at present, and the whole thing may be summed up by saying that at present the best bearing metal that we know of, is a copper-tin-lead alloy, containing a small amount of phosphorus, in which the proportions of the constituents are approximately those shown above.

It has already been stated that a satisfactory bearing metal should be of such a nature that it will sustain the

load without crushing; that it will work well in the foundry; that it will not heat readily; that it will make the friction between the rubbing surfaces as low as possible, and that it will give the highest possible mileage, with the smallest possible loss of metal by wear. It is believed that the metal which has been last described fulfils all these requisites as well as any alloy now known. Of course, the most important element; that is to say, the one which bears the closest relation to dollars and cents in a great corporation, is obviously the wear, and any light which can be thrown on this subject will, of course, have a tendency to diminish the operating expenses, or what amounts to the same thing, leave more money in the treasury of a corporation at the end of the year, so far as operating expenses are affected by bearing metal. In the course of our study on this subject, we have philosophized a little on the question of wear, and have endeavored as much as possible to find out what property it was in metals, which enabled them to resist loss of metal by abrasion. We have already hinted at the possibility of a law governing this phenomenon of loss of metal by wear, but the law, as enunciated, seems to be too narrow. Much light has been thrown on the subject from the study of other metals, and in other fields besides that of bearings; and in view of the importance of the subject, the following considerations, in regard to wear, may not inappropriately close this lecture:

Of course, wear is influenced by the conditions under which it takes place, and it is not my purpose to discuss those variables, which may fairly enough be called "concomitant conditions." I will, therefore, not discuss lubrication, pressure, speed, temperature, rolling friction, or abrasion, nor, indeed, the nature of the two metals rolling or sliding over each other, but will confine myself wholly to the qualities of metal which, all other things being equal, give least loss of substance by wear under the same service. To my mind, we are justified in assuming that at least three elements enter into the problem of wear.

(1) That metal which will suffer the most distortion without rupture will wear best. This quality of metal is usually

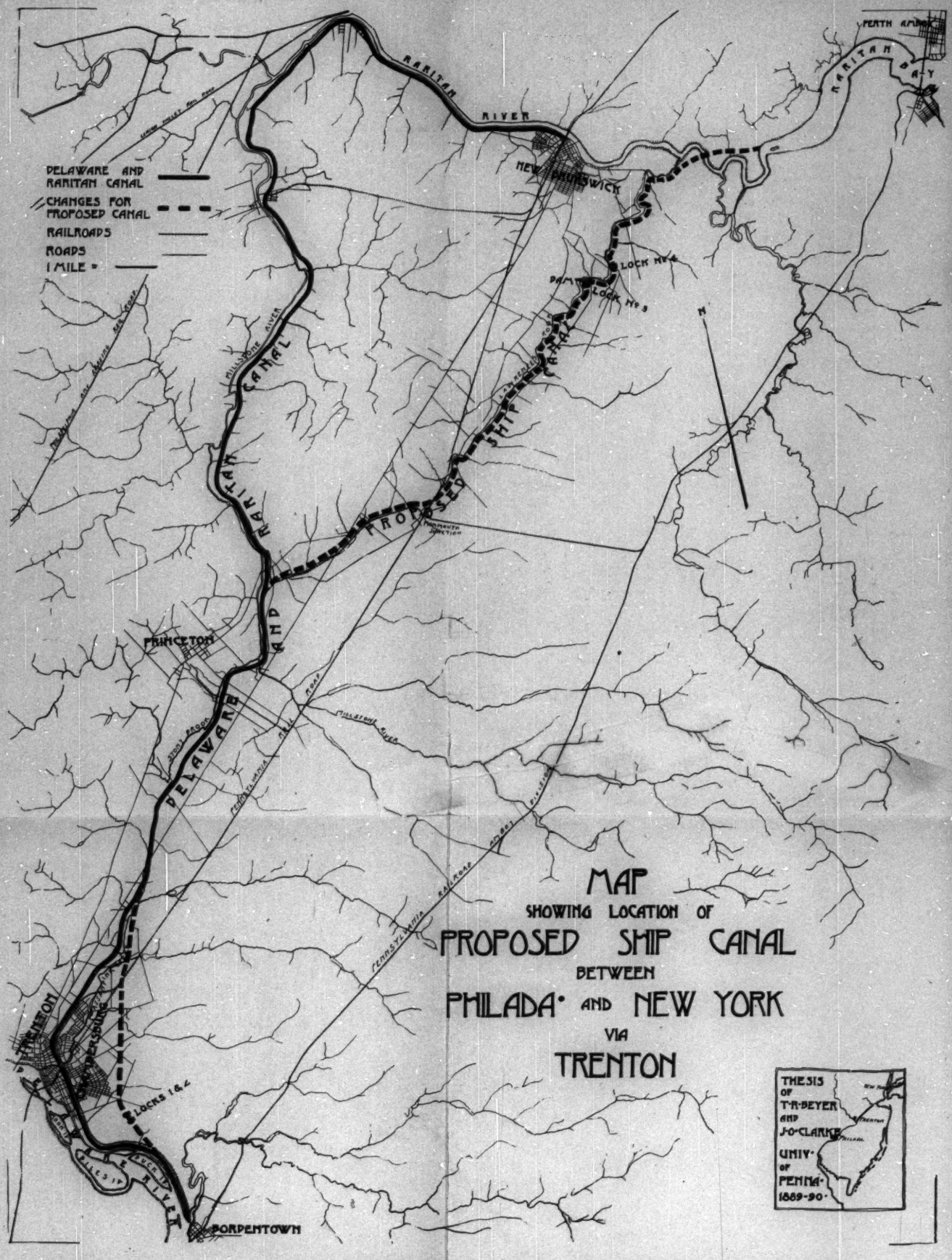
measured or expressed in figures by the well-known physical data "elongation" or stretch before rupture in the common physical test. Possibly the experimental data on this point is greater than we possess on any other of the variables which enter into wear. If we may trust the data which I have brought forward, and the conclusions drawn from them, in all cases the greatest elongation is characterized by the best wear; or, according to the law, that metal which is characterized by the greatest power to resist distortion without rupture will wear best.

(2) The first variable being obtained in satisfactory amount, an increase in tensile strength will add to the wearing power of the metal. The diminution of tensile strength, which is characterized by the better-wearing metals, according to our data, is not, if I am correct, a desirable quality. It is a concomitant of most metal, that as it increases in its power of elongation, or stretch, before rupture, it diminishes in tensile strength. If, on the other hand, a new metal could be found which, with any given elongation, was characterized by a higher tensile strength than some old and well-known metal with the same elongation, the new metal would, if the theory is correct, wear better than the old one. It is not difficult to say why an increase in tensile strength should be valuable in assisting wear, provided the power of distortion before rupture is not interfered with. Wear, as I understand it, is the tearing off of minute particles, and if in one case it requires more force to tear off the particles than in another, the wear in that case will be slower. We have, I think, some experimental data which point in this direction. The wear of bearings per thousand miles is about three times as fast as the wear of axles; in other words, as has already been stated, the standard phosphor-bronze bearing metal loses about a pound for each 25,000 miles that the bearing moves. The axle under it loses about a pound for each 75,000 miles, but the metal of the axle is from two to three times as strong per square inch, and its elongation is also somewhat higher than the bearing metal alloy.

The third variable which enters into wear, as I look at it,

is what may perhaps be termed the "granular structure of the metal." This may, perhaps, best be illustrated by saying that, of two metals which have the same tensile strength and the same elongation, the one which is finer in granular structure will wear the slower. This, we think, will be evident by returning to our conception of what wear is—namely, the tearing off of minute particles from the worn body. If, now, at each rupture of a particle of metal, the particle torn off is in one case twice as large as in the other, the wear will be twice as rapid, and we assume that, other things being equal, the granular structure represents the size or fineness of the particles torn off at each operation during wear. We have but few experimental data on this point. It is generally believed by those who have had a chance to make observations, that what is known as case-hardened iron wears better than either the wrought iron from which it is made, or than ordinary hammered steel of approximately the same carbon. It has also been observed that case-hardened metal is always characterized by an extremely fine granular structure, as evidenced by the fracture. This, of course, is only an observation, and cannot be taken as proving very much. It is also entirely possible that the influence of what is technically known as "tempering," on wear, may appear in the effect of the temper on the granular structure. The field is, of course, too void of experiment and too little known to warrant anything more than suggestions.

The relation and interaction, so to speak, of the three variables mentioned above is, of course, quite an unknown field. We are inclined to think that the experimental data which have been obtained point clearly to the conclusion that the increase in tensile strength at the expense of elongation is disastrous, as far as wear is concerned. An increase in tensile strength with an increase in elongation would unquestionably, we think, be valuable. The influence of the structure or granular condition may be even more important than either elongation or tensile strength. Of course, the data do not warrant any conclusions, but it seems not at all improbable that the size of the particle torn


DELAWARE AND RARITAN CANAL
CHANGES FOR PROPOSED CANAL
RAILROADS
ROADS
1 MILE =
RARITAN RIVER
NEW BRUNSWICK
PERTH AMBOY
RARITAN BAY
LOCK No 4
LOCK No 3
PROPOSED SHIP CANAL
RARITAN CANAL
DELAWARE AND
PRINCETON
TRENTON
BORDENTOWN
BLOCKS 1 & 2
MAP
SHOWING LOCATION OF
PROPOSED SHIP CANAL
BETWEEN
PHILADA. AND NEW YORK
VIA
TRENTON
THESIS
OF
T.A.BEYER
AND
J.O.CLARKE
UNIV.
OF
PENNA.
1889-90.

off, each time one is torn off, may be the most important variable in the rate of wear. It is also not improbable that if some method of measuring the granular structure of metal, and rightly estimating its influence on wear, was known, this information would go far toward explaining many of the anomalous cases of wear which, if my experience is worth anything, are almost universal accompaniments of experiments in this field.

To put the above ideas in very brief shape, I will say, that if anyone wants to design a bearing metal, the first four conditions given above as essential for a good bearing metal must be first met. Then make a metal which will have the highest possible tensile strength, coupled with the highest possible elongation, and add to this the finest possible granular structure, and you will have the best bearing metal that at the present time I know how to recommend.

The proposed SHIP CANAL between NEW YORK and PHILADELPHIA connecting the DELAWARE and RARITAN RIVERS.

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By Prof. Lewis M. Haupt, C. E.

[*Remarks made before the Franklin Institute at the annual meeting, January 20, 1892.*]

Mr. President, Ladies and Gentlemen:

It gives me pleasure to be able to respond to your invitation to speak on the subject of the ship canal across New Jersey, as it is one of great importance to the welfare of this community. It is a cause of regret to us that from various causes Philadelphia has fallen from first to about seventh of our cities in the rank of commerce, but we have the satisfaction of feeling that in manufactures she still retains her preëminence.

If we wish to hold this position in these days of keen rivalry, it behooves us to exert ourselves to cheapen the materials used in our industries and to extend our market

range, and it is, therefore, of interest to you as members of this Institute to consider the means whereby these results may be accomplished.

The market price of every article is composed of the cost of production and the cost of transportation. The former is a function of price of raw material and labor; the latter of the rate per mile multiplied by the distance traversed. This latter cost varies with the character of the resistance to be overcome, and is best measured and compared by reducing the load and distance to the unit of the *ton-mile*. Thus, for traffic on a common earth road in good condition the cost of conveying one ton one mile is about twenty cents; on a standard gauge railroad, well equipped, the average is .928 of a cent or nine and one-quarter mills, although for some articles in bulk the rate is as low as four and one-half mills. On canals of ordinary draught (seven feet) it is less than two mills, and on the great lakes or the ocean it is a small fraction of a mill. Even on the old-time canals, with their boats of limited capacity, the cost is less than *one-half* that by rail, with all the improvements that have been made. The reason is obvious. The mechanical resistances of a rolling train and the ratio of dead to live loads are much greater in the case of the rail than in that of the waterway. Moreover, the capacity of a boat may be increased as the cube of the depth with very little increase of power to propel it. The mere lengthening of the mid-ship section adds but little to the resistance while it greatly adds to the capacity. It is generally conceded that the railway cannot compete with the waterway, and hence the war of extermination. The canals of this country are being bought up and destroyed to enable the railroad to maintain their rates. This does not seem to me to be the best policy for the general good of this country, and it is not that pursued by our foreign competitors. They are now quite active in increasing the draught and capacity of their waterways, and in a few years Canada will have a fourteen-foot navigation from the Great Lakes to tide-water, while we have but seven. This will unquestionably divert the grain trade from our Atlantic ports to those of

Canada, unless it is met by a waterway of equal or greater capacity, which is entirely practicable.

I have been asked of what use would such a canal across New Jersey be to Philadelphia which now has a deep water channel to the sea. In reply, I would say, that it would extend the Erie Canal and its benefits to this port and open to our manufacturers over 16,000 miles of waterways in the great basin of the Mississippi. It would reduce the distance by water to New York harbor from 240 to about sixty miles, would afford an inside and safe passage to eastern, Sound and Hudson River ports; would develop a large population along the entire route, and so benefit the railroads traversing the district. In short, the effect would be to reduce the rate per mile as well as to shorten the distance between the two greatest centres of population on the American continent, or, we may say, in the world; for nowhere else on the globe is it possible by so short and inexpensive a waterway to connect such large populations and so many and valuable interests.

The real import of this reduction in both rate and distance is not fully realized; but it is equivalent in effect to a physical transportation of one or other of the terminals with all its appurtenances through a distance represented by the saving in cost of transportation, just as if a slice of the intervening earth were cut out and the two places brought that much closer together. It enables the market range of our articles of manufacture to be extended in the same ratio; in other words, if the rate per ton-mile can be reduced to one-half or more as it can be by water, its distance of transport may be more than doubled, and the tributary territory will therefore be expanded fourfold.

These are some of the great benefits to be conferred by the construction of this ship canal. Manchester, in England, is expending over $60,000,000 in a twenty-six-foot canal thirty-five and one-half miles long, merely to avoid the terminal and wharf charges of Liverpool, although there are already several canals and railroads connecting it with the sea; and should not we be amply justified in expending

a small fraction of this sum to secure results of so much greater magnitude?

I will not detain you to listen to the great importance to the nation of this link in the Atlantic coast waterway for defensive and strategic purposes. Suffice it to say, that it will treble the efficiency of our Navy and be worth many times its cost in saving expense for an otherwise larger armament and the cost of maintaining it,

The route proposed, as revealed by the topographic charts of New Jersey, is shown upon the accompanying map. It is but 33·75 miles in length, and will follow for about eleven miles the route of the existing Delaware and Raritan Canal. The summit level will be 50 feet above tide, and will be reached probably by two locks at either end of 25 feet lift each. These, with the two tidal locks, will make six in all. The cube of material to be removed to give a prism 90 feet wide at bottom, 150 at surface and 20 feet depth of water will be about 26,500,000 yards. The drainage basin tributary to the summit level embraces 301 square miles, and the highest point on the profile is but 76 feet above mean low water.

The physical conditions are believed to be unusually favorable for the enterprise, which is estimated to cost but $12,500,000.

Thanking you for your kind attention, I trust you will find the subject of sufficient moment to engage your earnest coöperation and support.

The DEVELOPMENT of SPIRAL WELD TUBE MACHINERY,

By Geo. Ross Green.

The following account of the development of spiral weld tube machinery may prove of interest to many engineers, especially those who have investigated new and unexplored fields of engineering.

During some nine or ten years prior to 1887, Mr. John B. Root experimented upon spirally welded tubes. The art of welding gun barrels with a helical seam extends back to the beginning of fire-arms; but in the gun barrel the whole body of metal is brought to the welding heat, while in the spirally welded tube the metal at or near the edge only is heated so high, the main part of the skelp remaining practically as it left the rolls. Mr. Root's patent is based upon this condition.

At the time of his death, December, 1886, Mr. Root had completed the machine shown in *Figs. 1, 2, 3, 4*, and had succeeded in making a few pieces of pipe, the longest being twelve feet, of eight-inch, which was never duplicated. This pipe, like the others, leaked badly when tested with water to a few pounds pressure only.

The operation of this machine is as follows: The driving pulley *F* is keyed to a small shaft, which passes through the hollow cast-iron shaft *V*, and has upon its end two eccentrics, which, by means of links, give oscillating motions to the two rock arms *C*. These are pivoted at one end of the shaft *V*, and upon the outward ends of the rock arms are fastened, forming jaws or dies with curved faces, which are expected firmly to grip the skelp and bend it a small amount, depending upon the diameter of the pipe which is to be formed. These dies were made of cast iron, firmly bolted to the rock arms, and were provided with water passages, either cored or bored in them, to allow for a circulation of water in order to keep them cool. Should the driv-

ing pulley now be revolved, the rock arms would oscillate to and from each other in one plane. In order, however, to secure a "feed," the rock arms were given a helical motion, which was secured as follows:

Upon the back end of the shaft V was keyed an arm L' which was connected with the link device, shown in *Fig. 4*, by the connecting rod M. This link I was pivoted at the left-hand end, and was given motion by means of an eccentric secured to the pulley shaft. By revolving the shaft C_2 the connecting rod M' could be shifted to any point of the links and any desired amount of circular movement; within limits, could thus be imparted to the shaft V. The forward

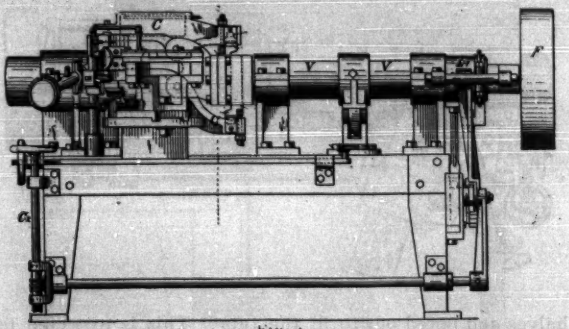

FIG. 1.

component was obtained by the mechanism shown at Q'. The slide block P' is so connected with the shaft V that as it slides in the guides Q' an end movement is thus given to the shaft V. The angle of the guides is set to correspond with the angle of the pipe being made.

The machine is so adjusted that when the dies clamp the skelp, the rock arms begin the helical movement, and the mechanism recovers its original position while the dies are separated. The skelp A is guided in a suitable table E, and the angle is set to give about one-half "lap" to the edges.

The fire-brick lined furnace K_2 is so arranged that one edge of the entering skelp passes into it through a slot in

the side for that purpose, and the opposite edge (which has by this time been formed into a cylinder) passes into the flame between the front of the furnace and the fire-brick lined "lip" O_2, *Fig. 3*, secured to the furnace. Both edges are thus simultaneously heated to the welding point, and are hammer welded as they emerge from the furnace. The hammer mechanism is not shown upon the drawings; but it consisted of two hammers, one inside the tube and one outside, which met exactly on the line of weld.

The tube *B* shows a burner which passes into the furnace. The pipe mould *D* is a hollow cylinder made in

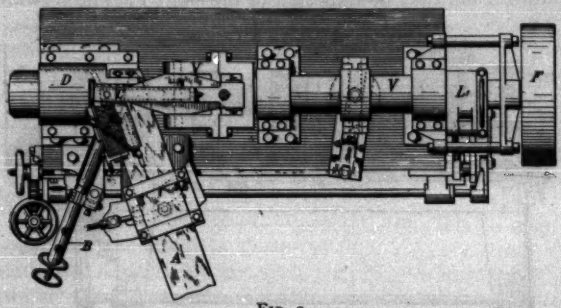

FIG. 2.

halves and bored out to fit the tube. This is expected to guide the metal, and keep the pipe of a uniform diameter.

This machine was never successful, and among its defects may be mentioned the following:

(1) The general designs and peculiar motions did not permit of making the parts strong enough to bend any but the thinner gauges of skelp.

(2) The feed was entirely too weak to be of practical value. The dies not only were expected to bend the entering metal, and feed forward the tube already formed, and draw in the straight skelp, but were also required to straighten out any inequalities made in the pipe by the hammers. As the weld was much thicker than any other point, the main strength of the dies was expended at this

point, which being in a semi-plastic condition allowed the jaws to slip when any extra force was required. The tendency of the pipe was to enlarge, and this it would do until the friction against the furnace and pipe mould was greater than the strength of the feed; then the pipe would stick and a hole was burned in the skelp. As a rule, not more than four feet of pipe could be made before this point was reached. I have been able, by pulling on the entering skelp, to overcome the strength of the feed.

(3) Adjustment for different thicknesses of skelp were difficult and tedious to make, as the back ends of the dies would grip the metal before the front ends, unless properly arranged.

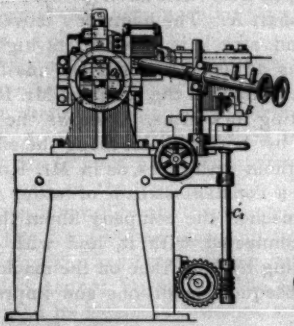

FIG. 3.

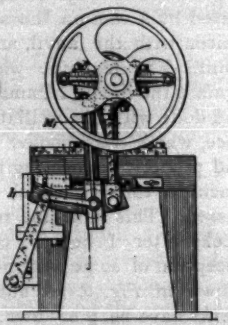

FIG. 4.

(4) The axles of all pipes were the same, and to change from one size to another was a long and unsatisfactory operation, as it required new dies and new hammers, both of which met the pipe at its topmost point.

The Spiral Weld Tube Company was organized about the time of Mr. Root's death, and as he had left no data of value, Mr. Thomas S. Crane, who had examined the machine with the inventor, was engaged to design a new machine, which is shown in *Fig. 5*.

For the clumsy jaws having the helical motion, Mr. Crane substituted feed rolls on the skelp table, which were controlled by a friction device *A B* in the rear of the

machine. This consisted of an iron plate *B*, upon which was fastened a sheet of leather, and this plate was given an intermittent motion through the oval gears *C*. *A* was a friction wheel rubbing against *B*, and so arranged that it could be moved to or from the centre by turning the hand wheel *D*. Upon the same shaft as *A* is a worm engaging the worm wheel *E*, and this rotated the feed rolls by means of a shaft, upon which are universal joints *F*.

The pipe mould *G* was a casting bored out to fit the pipe, as in Mr. Root's machine, and upon one side was arranged the fixed former *H*, upon which was fastened a die extending about three-quarters across the skelp. The lower die was mounted upon a movable anvil (pivoted at *J*) raised by a cam on the shaft *K*. The hammer *I* moved in unison with the anvil, and struck it when at its highest point. The machine was adjusted to force the anvil die against the die on *H*, and thus bend the skelp as Mr. Root had done with his oscillating rock arms. *L* shows the furnace, which was cooled by boring holes along the edges and properly connecting them with pipes, as in Mr. Root's machine, through which a constant stream of water was passed. This machine reached the company about three weeks after I became connected with it, and with the exception of some designing by Mr. Crane on the machine, shown in *Fig. 6*, all subsequent additions and improvements have been my own.

No pipe could be made on the machine shown in *Fig. 5*. Upon starting up, the friction discs driving the feed rolls were found to possess insufficient power to force forward the pipe. They would slip in spite of every endeavor to improve them, and were replaced by a positive ratchet mechanism, which was found to answer admirably.

A cylinder could be formed of the cold skelp; but as soon as heat was applied and the edges united the pipe would bind so tightly in the pipe mould that it was necessary to split the pipe longitudinally with a cold chisel to remove it. After several efforts to overcome this, the pipe mould, as shown, was thrown in the scrap and a new one, one inch larger in diameter, was cast to take its place.

Through the shell of the latter, anti-friction rolls (to support the pipe) extended, secured in suitable frames, which were bolted to the pipe mould (see *Fig. 6*).

It was impossible for dies "crimping" but three-quarters of the skelp to form a cylinder, and new dies were arranged double the length of the others. An effort had been made to cause the hammer to take the place of this extension of the dies by bolting to it a curved block, as shown in *Fig. 5*; but this was found to be worthless. The machine was now tried, and a few feet of pipe were made upon it—the longest perfect piece being about four or five feet.

This machine had been so radically changed that it was decided to throw it in the scrap, which was accordingly done and another machine, shown in *Fig. 6*, was built to take its place.

I found the fixed upper die in *Fig. 5* was a great disadvantage, as the friction against it was enormous; and it was therefore arranged to have an oscillating movement (see *A*, *Fig. 6*). The method of mounting this crimper was Mr. Crane's, and he has arranged the axis parallel with the axis of the pipe, which renders it an easy matter to adjust it for different thicknesses of skelp.

The die fastened securely to the crimper *A* is shown at *A'*. The anvil was raised vertically in suitable guides, which cannot be seen in the figure, and the motion was secured by means of a wedge, actuated by the rock arm *B*.

Motion is imparted to the rock shaft *C* by means of the universal joint connecting rod *D*. The link for driving the ratchet *E* is shown at *F*, and the position of the slide block is regulated by the hand-lever *G*.

The pipe mould is shown at *H* with a number of roll frames fastened to it. The corrugated friction feed rolls are shown at *I*, the furnace at *J*, and the hammer at *K*. By arranging a flat place on the top of the wedge which raised the anvil, the latter reached its highest point and dwelt there for a small interval of time, during which both the die *A* and the hammer *K* had performed their functions. The ratchet was adjusted to feed forward the pipe only when the anvil was down, and the die *A'* and the hammer *K* raised.

In order to cool the hammer a water pipe was arranged to throw a small stream against it when at its highest point.

This machine had but one defect; no pipe could be made upon it; *i. e.*, no more than on Mr. Root's machine. It corrected nearly all the defects found in the latter, but it also introduced others which Mr. Root had not encountered.

Mr. Root had run his machine but a few minutes at a time. Efforts were now made to run this machine steadily, but with most discouraging results. The anvil was continually expanding and binding in its guides, so that the belt could not drive the machine. The horn of the anvil and also the dies were continually burning and warping out of line; the hammer would heat to bright redness in three or four minutes; the furnace would crack and allow the water to escape into the fire space, where it was converted into steam, and welding was therefore impossible; and the pipe itself was so corrugated by the hammer and the rolls in the pipe mould that most of it went to the scrap pile. The pressure of the pipe against these rolls was enormous, and they were continually being forced or skewed out of place. The feed rolls were not powerful enough to drive the skelp and pipe forward, and whenever the pipe stuck—which happened with almost every piece—it was necessary to remove the furnace in order to loosen it. To do this required the detachment of the casting holding the fire-brick "lip," which was bolted to the furnace, and as there was practically no clearance at this point and all parts were exceedingly hot, this was by no means an easy operation, and it usually took from one to five hours in order to repair the machine after every such mishap.

At this juncture two ideas occurred to me, and from their introduction may be dated the successful manufacture of these tubes.

First, if the anvil was made stationary the tendency of the pipe to rise from it would prevent binding, and the heating could be done quite as well. Also the "lip" could be secured to the side of the stationary anvil, which would render the removal of the furnace an operation of a few minutes only.

The second idea was to make the pipe moulds in sections having inclined seats upon them, thus rendering it a simple operation, by the use of jigs, to set the rolls securely at the mathematical angles.

This was the end aimed at, but never attained in my other pipe mould. These guide blocks thus formed cost much less than the old pipe mould. The anvil was cored out for a water space, the hammer was properly water cooled and its speed doubled, and the feed rolls were geared together.

I also found much difficulty with the dies. It is necessary in order to form these tubes that the machine should be in good alignment. The dies for 6, 8 and 10-inch pipe are 17 inches long, and for 12 to 24-inch pipe about 37 inches long, and these were necessarily so arranged that an intense blow-pipe flame played upon them continually at one point. If made of cast iron they would heat to redness in a few minutes. If cooled by having holes bored in them they would crack and allow the water to spirt through the holes. If made of cast steel and water cooled they would warp in a very short time. If made of wrought iron they would do the same, though not so soon. To bore these out for the water passages was a very expensive operation. This difficulty was solved by casting one-half inch water pipes in the dies and dressing them afterwards. It was also found that fastening the upper die solidly to the "crimper" was not advantageous, and a seven-eighths inch steel rod was half set in the "crimper" and riveted through, and the die was grooved out to fit this rod and secured to it loosely, thus facilitating its seating upon the pipe.

The furnace also had a small pipe cast along the edges next the fire, and the furnace was given a shape different from that of Mr. Root's. Two burners were arranged to enter it, and the proportions of gas and air were experimented with in order to get a reducing flame. As soon as these improvements were put upon the machine it was again tried, and a thirty-two-foot length of 10-inch pipe perfectly straight was made without hitch or trouble. A few days' running showed the machine to be too weak, and a new machine, shown in *Figs. 7, 8* and *9*, was built. In this

machine all the improvements mentioned above were incorporated, and also an extra set of feed rolls was mounted on the skelp table. In the previous machine the feed roll housing was fastened to one side only, and overhung the skelp. In addition to that an extra set of feed rolls, shown at *A*, was arranged with bearings on both sides of the table, which materially assisted in the feeding of the large pipe. The hammer *B* was forged of machinery steel, and water pipes were conducted to it as shown. At *C* can be seen the pipes for cooling the top die; at *D* the guide blocks with the rolls mounted upon them; at *E* the hammer connecting

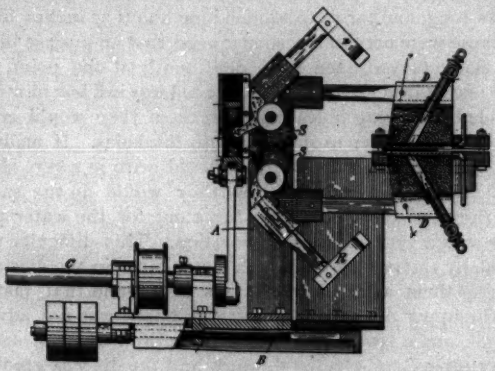

FIG. 10.

rod with buffer stuffing boxes to regulate the blow, which must be light and rapid; at *F* the universal joints on the shaft for driving the feed rolls; at *G* a forward feed device consisting of a ring revolving in a suitable frame with the rolls set at the reverse angle from the guide blocks. These rolls were mounted on blocks, which, by means of springs, allow for any inequalities in the tube. This device is practically a left-hand nut, and it is exceedingly powerful, though it is found that the main feed rolls as a rule are able to feed the pipe alone.

Over 800 feet of perfect six-inch pipe have been turned out

upon the new machine in ten hours. This is nearly double the amount originally estimated.

Fig. 10 shows the cross welder constructed by Mr. Root, and *Fig. 11* our present one. In *Fig. 10* a suitable frame *A* is moved backwards and forwards by means of the screw *B*. Mounted on the frame are the two hammers *R*, which are geared together by the segments *S S*, the revolution of the hammer shaft *B* causing the hammers to oscillate to and from each other and meet on the line of weld of the straight skelp, which is clamped on each side of the fire-brick lined furnace *D*.

This machine had no method of varying the feed, and the new cross welder, shown in *Fig. 11*, was built, which was run in connection with an Evans friction cone counter shaft, so arranged that the return motion is rapid and the

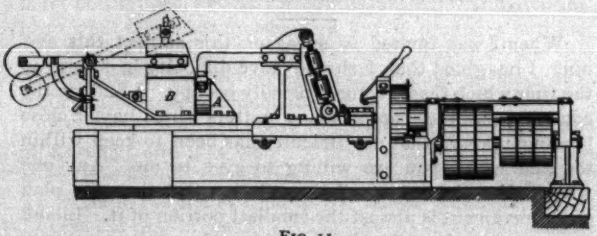

FIG. 11.

speed constant, while the forward movement can be varied at will.

The stationary anvil *A* and the furnace *B* are provided, and this machine is able to handle heavy gauges of skelp rapidly and easily.

In these machines one of the most serious problems has been the gas and furnace problem. To continuously heat two edges of a light metal to the welding point, with not more than a foot in the flame at any one time, and to feed this through at the rate of from twenty to forty inches a minute and weld it, is a problem which must be seen to be thoroughly appreciated. Directing the burners a one-half inch higher or lower will often make the

difference between success and failure. The distance of the burner from the weld must also be nicely adjusted—if too close an oxidizing flame may be the result, and if too far away the proper heat will not be secured, both of which will prevent welding. Were there but one edge to be heated the matter would be comparatively simple; but when it is considered that there are two edges and the metal is often no thicker than the sixteenth of an inch, it can readily be appreciated how difficult and delicate is the operation, and it was this problem, as well as the machine, that the inventor bequeathed us to solve in a practical and profitable way.

PHILADELPHIA AS A SEAPORT.*

By Capt. F. A. Mahan, Corps of Engineers, U.S.A.

When I was invited to speak on this subject this evening, I imagined that I should have difficulty in filling up the time which these lectures usually occupy. I find, on the contrary, that there are so many matters which have a close bearing upon it, that my difficulty has been to keep within the time which you are willing to give to me. Any one who studies the case carefully will soon find that the plan of improvement is almost the smallest portion of it. Inland transportation by rail and water, financial questions, politico-economical considerations have features to be examined, and to treat of all of them would need the services of lecturers for a season. Still they are not only germane to the cause, but they are of vital importance, and the objections raised by their study must be met before work can be put on a fair and sure basis. As these cannot all be discussed to-night, I shall only touch on some of them lightly in speaking of

PHILADELPHIA AS A SEAPORT.

Philadelphia, the third city of the United States as regards population, the first or second as regards manufac-

* A lecture delivered before the Franklin Institute.

tures, is situated on the right bank of the Delaware River, at a distance of about 100 miles from the ocean. Connected with the interior of the country, as it is, by means of three great railway systems we should expect to find it the centre of an extensive trade by sea. We all know that this is not the case.

What are the requirements of a great seaport?

(1) Vessels must be able to come in and go out at all times loaded to their full capacity.

(2) Ready means must be at hand whereby one cargo may be removed and the next one stored.

(3) There must be plenty of space whereon goods arriving or going out may be placed temporarily after discharge or before shipment.

(4) Transportation to and from the interior of the country must be supplied, as a city produces nothing. It may transform what is produced elsewhere, but it produces nothing.

(5) Opportunities for having vessels trading at the port repaired must be provided, and they must be such that work can be done at reasonable rates.

Examination of the above requirements shows that they all have one object in view: to prevent loss of time. There is no truer saying in our language than "Time is money." To explain the application of the above requirements let us take the case of a ship costing (say) $300,000, and assume that she is expected to net her owners six per cent. on the investment. This means $18,000 a year, or about $50 a day. In order to earn this a certain amount of freight must be carried in the course of a year; in other words, a certain number of voyages must be made. In the length of the voyage must be included not only the time at sea, but also the time of discharging one cargo and taking in another, the time of removing the former from and delivering the latter at the wharf, the time required to go from the open sea to the wharves and the time to return.

Let us suppose further that under the natural conditions she is able to make six round trips a year to the home port from the foreign port. Suppose now that the foreign port makes improvements whereby the time needed between the

open sea and the wharves is reduced one day in each direction, and that the time required to discharge and receive cargo be reduced from two weeks to one, we have a clear gain on each voyage of nine days. On the six round trips there is a gain of fifty-four days, or very nearly an additional trip in the course of the year. In other words, the income from the investment will amount to seven per cent. nearly instead of six. If a port then shows that by its improvements or advantages, vessels can make their voyages with a minimum loss of time, that is the port, all else being equal, which will be most frequented.

Let us examine the port of Philadelphia in regard to the above requirements.

In order that vessels may be able to come in and go out at all times, loaded to their full capacity, two things are required: (1) The waterway must be ample; (2) it must be clearly defined. A reference to the map shows the waterway, and the method of defining it. A description of Delaware Bay and river, as they are found by a vessel coming from sea, gives us first a break eleven and one-half miles wide in the shore line. This break is the mouth of the bay. Before entering there are shoals to be avoided. Those lying near the New Jersey end of the imaginary line joining Cape May with Cape Henlopen, are McCries', Epps', North, Middle and South Shoals, Mummy and Round Shoals. The last two are on the bay side of the line. Just off Cape Henlopen is the Hen and Chickens' Shoal. Between these there is a channel of generous width and ample depth so that vessels drawing thirty feet may enter the bay at any tide, and go up to a point half-way from Ship John Shoal light to Port Penn.

After entering the bay the channel is very straight, and is well marked by means of lights for night travel and by day-marks and buoys for day trips.

After passing the light-house at Ship John Shoal, a vessel runs straight on the range indicated by the two lights at Port Penn. A little above the front light of the Port Penn range is the Reedy Island light. This light has a red cut, and so soon as a vessel enters the red, her course is

changed to the right and the Finn's Point range is taken up and held until the New Castle range is found. This range is followed until the vessel enters the red rays of the Finn's Point range rear light, when the course is again changed to the right to the Deep Water Point range. Hence the vessel follows the Cherry Island Flats, Schooner Ledge, Tinicum Island and Fort Mifflin Bar Cut ranges up to what is called the Horseshoe, a curve in the river just above the mouth of the Schuylkill. The ranges here are indicated by limits shown by the lights of the E. and W. groups.

It has now been shown how vessels reach Philadelphia. It is not possible for vessels of the largest size to come up the river for the reason that the depth of water is insufficient at some points. The rise of the tide is, on an average, about six feet. Vessels to be safely and easily handled should have a clear foot and one-half or two feet underneath them. There are places in the river below the city where the depth at low water does not exceed twenty-one or twenty-two feet. Add to this six feet for rise of tide, and we get twenty-seven to twenty-eight feet actual depth of water but only twenty-six or twenty-six and one-half feet available depth.

The formation of these obstructions or bars takes place usually down-stream. It is the result of the action of the various forces developed by tides, winds, rains and passing objects.

Beginning at Bridesburg we find a good channel with twenty to thirty feet of water until we reach Fisher's Point, a little below which is Five-mile Bar, a shoal which starts from the north shore of the river between Bridesburg and Richmond and makes southwardly and westwardly to the head of Petty's Island, obstructing both the channels about the island. The channel north of Petty's Island, between it and the city, is good and has plenty of water.

To cut away the bar a Board of Engineer officers recommended, in 1885, the construction of a dyke from Fisher's Point toward the head of Petty's Island. This dyke was built 3,000 feet long in 1886 with its top at the level of mean low water. In 1888 it was seen that to accomplish its work

the dyke should be lengthened 1,000 feet and should have its top raised to eight feet above low water. This change caused a marked gain in the action of the dyke and an increase in the depth of water on the bar from eight to eleven and one-half feet, with a breadth of 500 feet, at low water.

Coming down stream we find plenty of water all along the city front until we go below the mouth of the Schuylkill River.

Lack of depth is not the only obstruction to the free use of a stream. Surface room is needed; in other words, width of channel, so that vessels may pass each other, and, when necessary, have space in which to turn around. This space is seriously lacking in front of the city. It exists from above Petty's Island to the lower end of Smith's Island. Between these two islands the river makes a bend of 90°, passing from a westwardly to a southwardly course. The bar which began above Petty's Island continues downstream and is finally lost below Smith's Island. The channel between these islands and the New Jersey shore is too shoal for deep draught vessels.

For a long time it has been recognized that these islands are greatly in the way. Much time and thought has been given to what is best to be done for the good of the harbor. The matter was referred to a Board of Engineer officers in the spring of 1888 and they recommended the removal of Smith's and Windmill Islands and a slice of Petty's Island, and the establishment of two lines as the boundaries beyond which the ends of the piers on the two sides of the river should not extend. The price of the two small islands and the slice of the larger having been fixed, it was paid by contributions from the United States, the State of Pennsylvania and the city. An appropriation for beginning the removal of these obstructions is contained in the last River and Harbor Bill, and specifications for doing the work are now under preparation by my colleague, Major C. W. Raymond, Corps of Engineers, who is in charge of the improvement of the Delaware River.

Continuing our way down the river we come to what is

known as the Horseshoe, in which the main obstruction is the winter's ice. This is kept from blocking the river by ice-boats, which are very powerful tugs especially fitted out for the purpose of breaking up the ice so that it may float off in small chunks.

Beyond the mouth of the Schuylkill we find two deep channels, separated by the Fort Mifflin Bar, which takes its name from the near-at-hand Fort Mifflin, one of the old-time fortifications of the city. Before 1873 this bar had not more than seventeen feet of water over it. In that year dredging was begun in order to deepen the water, but on account of the position of the cut it silted up again very soon. In 1878 the direction of the cut was changed and it was dredged to a depth of twenty-six feet and a width of 500 feet. This depth was increased by scour to twenty-eight and thirty feet, but it did not last long as we find that it had diminished to twenty-four feet in 1880, and to twenty-two feet in 1881; the width had also been reduced. In 1883 the attempt was renewed with no better results. The Board of Engineers of 1885 recommended the construction of a dyke from Hog Island to Maiden Island, and extended, perhaps, to Tinicum Island; the dyke to be built up gradually to the level of mean low water. This dyke was begun in 1885 and finished to Maiden Island in 1888. It is 7,000 feet long and made of rip-rap laid on brush mattresses. The object of this dyke was to deflect the main part of the water which flowed between Tinicum Island and the Pennsylvania shore into the better channel east of the island. In order to hasten the deepening of the channel and to see if the dyke could maintain it a cut was dredged during October and November of 1888, 250 feet wide, with a least depth of twenty-six feet at the sides and twenty-eight feet at the middle. Surveys made from time to time show that up to May, 1890, a gradual shoaling went on, so that in that month only 25·6 feet was found. But the dyke has had a great influence in that neighborhood, as the depth of water on the shoal has increased from one to three feet over a space 8,000 feet long and 1,200 feet wide. Built to the level of low water only, the dyke could not maintain a channel 600 feet wide and 26 feet

deep. In accordance with the experience had at Fisher's Point, the up-stream half of the dyke will probably be raised to two feet above mean high water. It is possible that an auxiliary dyke may have to be built out of the New Jersey shore.

Continuing our trip down the river we come to Schooner Ledge in the middle of the channel between Chester and Marcus Hook. This obstruction is a ledge of rock over which, in 1879, there was a narrow channel twenty-four feet deep, while close by it were points of rock standing under eighteen or nineteen feet of water. Inasmuch as blasting under water is more difficult and more expensive than mere dredging, the opening of a channel here has cost much, but when opened it stays. A recent survey shows that by re-adjusting the range lines a channel 1,600 feet wide and 26 feet deep can be had at much less expense than supposed.

Next beyond Schooner Ledge we find the Cherry Island Flats, extending from about Edgemoor to a little below the mouth of Christiana Creek, on which is situated the busy little town of Wilmington. In 1879 this shoal was two miles long, with only seventeen to twenty-two feet of water on it. Dredging was begun during the years 1879–80, and has been continued steadily since then. The channel has now a depth of twenty-six feet and seems to be permanent.

A little below New Castle the river suddenly widens and at the same time makes a sharp bend, changing its direction about 65°. The change of direction from the Deepwater Point range to the New Castle range is very gradual along a curve of which the ends are defined by the red sector of the Finn's Point range rear light. About half a mile above the upper radius of the sector the shoal begins to have less than eighteen feet of water at low tide. Following the bend of the river the shoal gradually gains height and finally develops as Pea Patch Island, on which stands Fort Delaware, another of the old-time defences of Philadelphia. This shoal is known as Bulkhead Shoal, about the most troublesome place on the river. Vessels were reported in 1880, 1881, 1882 as having constant delay there, running

aground and having to wait for high water. Dredging had been tried there, but with almost no success.

It will be noticed by the positions of the four-fathom curve above and below the shoal that there are apparently two channels, one formed by the ebb and the other by the flood tide. The ebb channel is the one to the eastward, and it is constantly shifting a little more to the east. The flood or west channel has a motion to westward. They are thus moving apart.

To improve this shoal two dykes are proposed, their position and extent being determined by the conditions: (1) To deflect the currents on the bar and make them aid in getting and keeping the desired depth; (2) to check the hurtful changes now in progress; (3) to connect the deep water above and below the bar by a channel having a direction convenient for navigation. One of these dykes is to begin at the head of Pea Patch Island and extend up-stream. Its middle and lower parts are intended to train the flood currents on the bar and prevent the westward movement of the flood channel, while the upper is to catch part of the ebb down the Delaware channel and add it to the current from the east dyke, which starts from the New Jersey shore and passes obliquely across the ebb channel to concentrate the ebb current on the bar. These dykes are not yet under construction. They will be built up to the level of high water.

Below Pea Patch Island a bar extends to a point abreast of where the New Castle and Finn's Point ranges intersect, the water regaining a depth of eighteen to twenty feet. Opposite this spot is found Reedy Point on the Delaware shore, whence begins a bar which gradually rises and forms Reedy Island, at the down-stream end of which is a light having a red sector to indicate the point of turning from the Port Penn to the Finn's Point range.

Just at this turn the water loses its depth and the place is called Baker's Shoal. To correct this place the Board of Engineers of 1885 recommended the construction of a dyke about 25,000 feet long, beginning at the lower end of Reedy Island. Of this dyke nearly 6,000 feet is done. Just below

this shoal the river narrows again and the channel depth becomes great until a point about three miles above Bombay Hook Roads is reached. In this stretch of three miles the water is about twenty-one to twenty-two feet deep at low tide, with six feet more when the tide is up. After once reaching Bombay Hook Roads vessels have no further difficulty so far as depth of water is concerned.

The shoals of the river have taken up a good deal of our time, but this has been necessary in order to show that Philadelphia lacks the first essential for a great seaport. The largest vessels cannot come here because there is not sufficient water. In fact I believe that the greatest draught of a vessel leaving the port is twenty-seven and one-half feet. With the present channel the pilot who takes out a vessel so deep in the water must know every foot of the road from the city to the sea better than the majority of my hearers know the floors of their houses; he must have plenty of nerve and keep perfectly cool. With these and no bad luck he may succeed in going through, but there is an element of risk of which few men will care to shoulder the responsibility.

We therefore dismiss the first condition as unfulfilled.

The second condition is that ready means must be at hand whereby one cargo may be removed and the next one stowed.

Let me here call your attention to an important point which, it appears to me, is frequently overlooked in discussing this question. With very, very few exceptions no city is a producer. It may be a manufacturing place gaining its prosperity by transformations, or it may be commercial and find its riches by transhipment from one style of conveyance to another.

Cities on the seashore, and indeed on most navigable highways, partake more or less of both characters, seeing that no matter to what extent mere commercial business is carried on there must also be more or less of manufacturing. In fact, the very necessities of a town must cause the changes in raw material required to meet the wants of the people. As illustrations I may mention Savannah and New

Orleans as essentially commercial cities, while Philadelphia is essentially manufacturing, and New York partakes largely of both sorts, the commercial predominating.

Now, as a city produces nothing, everything must be brought to it, and consequently facilities for handling should be provided. Considering our special case, Philadelphia needs enormous quantities of raw materials. With all her great shipyards, machine shops, woollen and cotton mills and factories of so many sorts that to mention them would require an evening, she does not produce a single initial effect. The ore, the raw cotton, the wool, the wood and the thousand other things which she transforms into articles of use or luxury must every one be brought to her, and not only they but two great elements of change, fire and water, have to come from afar.

In general terms then we may say that the essential feature of a city's existence is labor in some shape or other. Labor is mainly the cause of increase in the value of material. The value of a tree standing in the forest, or of ore buried in the ground is as nothing when compared with the finished products obtained from either. Labor must first be expended to fell the tree or delve the ore. It appears at every turn, and when it ceases to act the material comes to a stop, and there stays.

In a manufacturing city, then, there exists one great part of the increase of value, labor. But labor without material is nought. Material can be brought to labor much more cheaply than the reverse operation can be performed, therefore where the aggregation of labor is there exists the means of transformation. A manufacturing city must have material and that material must be handled. Handling must be done at the lowest possible cost, else the price of the material is unduly increased and, indeed, may be made prohibitory. We may conceive of a vessel-load of coal being discharged by carrying it out in hods on men's shoulders. It would be a very slow process and would add enormously to the price of the fuel. Now, as the cost of the finished article must be kept as low as possible in order to compete to advantage with other places, the cost of handling the

material must also be kept at the lowest limit. Machinery, therefore, is necessary, in plenty and of the quickest-acting type.

How ill provided with this machinery are the Philadelphia wharves and piers is patent to him who will look at them. To any one who has seen the splendid equipment of almost all the great foreign seaports this lack in our own is not pleasant to contemplate. To mention only one case I will speak of Antwerp where along the entire length of the quay are found at intervals of about thirty-five feet, nozzles to which movable hydraulic derricks may be attached, and these last are so numerous that, if necessary, it is almost always possible to have two of them working at each hatch of a vessel. This sort of thing struck me everywhere. At London, Liverpool, Marseilles, Genoa, and at other points I found the same equipment of quick-acting machinery made necessary by the sharp competition existing among these ports. In this, as in manufacturing, economy of time and labor is sought. Consequently a machine is used which does not get out of order and which needs no more intelligence to handle it than that which is sufficient to throw a lever. So far as I have been able to learn we may say that the port of Philadelphia is unprovided with ready means of discharging and loading vessels. The second condition is therefore unfulfilled.

The third condition is space for storing cargoes discharged or waiting to be taken on board.

How many piers are there along the water-front of the city where two cargoes of a trans-Atlantic liner could be stored? Not one, I venture say, unless it be in the possession of a railway for its own use. But it has been found in the great foreign ports that it is necessary to have this space, so that the operations of unloading and loading may go on without hitch or hindrance. Where the service is properly organized, no difficulty is encountered in doing this. In some places there are platforms, separated by passages, devoted alternately to incoming and outgoing merchandise. By this arrangement time is saved and an element of expense reduced.

As secondary to the second and third conditions we must have convenience of access for vehicles of all sorts, whether drays, cars or anything else for bringing or taking away freight. These require space in which to move freely. Where the space is not, there we find crowds and jams, hard to handle and sometimes almost impossible to untangle. A very short walk along Delaware Avenue will convince the most sceptical that there is no convenience for transportation. Then, too, how many piers can be reached by cars? When I say reached, I do not mean simply arriving at the root of the pier, but going out on it so that their loads can be transferred direct to the vessel, or *vice versa*.

Contrast this state of affairs with the great spaces along the quays at Genoa or Marseilles or Antwerp or many another foreign port. New York is beginning to wake up to the necessity of space, and at some parts of West Street may be found a width of 100 yards from the bulkhead back to the building line. This is none too much for the free circulation of a large trade.

We may say that the third condition is unfulfilled.

The fourth condition of transportation to and from the interior is fairly well met. Three important lines of railway centre here, and through them any part of the country may be reached. Still, here I think is the greatest drawback to Philadelphia's endeavor to become a great port. She can, without doubt, rival every city on the coast except one, because none of them is much better off than herself, but in the struggle with New York she is greatly handicapped by the Erie Canal. That, after all, is the great secret of New York's success, and only after it was built did New York begin to outrank Philadelphia as a seaport.

I remember some years ago seeing the remark made by a French writer that no seaport could become great without water communication with the interior. This is true within limits. Foreign nations understand this much better than we, and they are constantly adding to their canal systems. A boat can now be sent, in France, from Dunkirk on the North Sea to Marseilles on the Mediterranean and thence to Bordeaux or Havre on the Atlantic.

Belgium is a network of canals, and Germany is studying the subject with many great projects in view. In France the most enlightened development has taken place and canals are constructed on a uniform gauge after the manner of railways. So fully is the value of these navigable highways appreciated, and so well is their function understood, that some of the most powerful railway companies are their enthusiastic financial supporters, realizing that there is much which canals can carry as well as they, and at cheaper rates.

In our own country, unfortunately, there is almost no one to look after the canals.

Mr. Albert Fink, the head of the great railway pooling interests, testified before a Committee of the Senate that water transportation is the one check on railway rates. Compare the cost of transportation of grain from Chicago to New York when the Erie Canal is open and when it is closed. It is to the interest of the railways to close the canals; and to them may be traced the cry that canals are out of date. Legislators are easily influenced by passes over the railways, and canals having nothing to offer, suffer. If the same improvements had been made in canals which have been made in railways, if the same study had been given to them, if the same care had watched over their interests, we should not hear to-day that canals are useless. Even in its present old-time condition the Erie Canal carries in seven months one-third of all the grain going to New York during each year. In other words, the many lines of railway centring in New York, with all their modern improvements, require six months to do what the one old-fashioned canal does in seven. I am convinced that the last chapter on American canals will not be written for many a long day.

But we are not here to discuss canals. Still these few words seem germane to our fourth requisite of interior transportation.

The fifth condition is that vessels trading at the port must have opportunities for making repairs at reasonable rates.

I have not had the time to investigate this subject in Philadelphia, but I do know that in New York no foreign ship will make repairs if they can possibly be put off until the home port is reached. From the little I have heard, however, I should judge that the cost of repairs in Philadelphia is such as to make a vessel try to have them done elsewhere, and, furthermore, the facilities which exist here at the present time are not sufficient for an extended trade.

Having shown to what an extent the port is lacking, let us look around a little and see what can be done to remedy defects.

The policy of the general government is simply to make the path of a vessel clear from the deep sea to the port, or from one port to another along a stream. Under no circumstances has it ever undertaken to improve the commercial facilities of a city so as to simplify any of the operations of unloading or loading cargo. It does take under its charge all the improvements which come under the first condition of a seaport, that vessels must be able to come in and to go out at all times loaded to their full capacity.

We have already seen what has been done at many points along the river and it is likely that work will be continued along these lines for a long time to come.

The many calls made on the treasury, the absurd jealousy of one part of the country as regards the others, the uncertainty of appropriations, are all so many forces retarding the completion of any given work. So long as the press of one city regards the work in its neighborhood as all-important, and denounces all work done elsewhere as robbery, as a political job, as unnecessary to the commercial interest and development of the country, just so long will Congress be hesitating in the matter of appropriations. Then, too, it must be acknowledged that much is included in the appropriations which would better be left out. Members of Congress are but human after all, and so long as the services of any one of them are judged by the amounts of money obtained for his district, just so long must unworthy measures clog the completion of those which are good. Still, these unworthy items are by no means so many, nor do they

involve the sums which the outcries of the press would lead us to suppose. Taken as a whole, there is probably no item of expenditure made by the people of these United States which brings in so large a return in increased prosperity for the whole as this same much-abused and roundly-denounced River and Harbor Bill.

There is no doubt that more would be accomplished for the money spent if the people would consent to leave the direction of funds in the hands of disinterested persons who could weigh the merits of each case and determine the early finishing of works of prime importance, leaving the secondary and tertiary ports for later consideration. But the people will not have it so, and the treatment of ports is very often, in respect to funds, inversely as their commercial values.

These points may explain why Government work is generally so slow in completion. They are mentioned here to explain the cause of the great length of time which must probably pass before the works for the improvement of the Delaware are done.

The second, third and fifth conditions must, under our system, belong either to the city or its citizens, but before considering them let us take a look abroad and see what is done at some of the more important points.

A person who has not interested himself in going among the great seaports, and indeed, among many of the smaller ones, can have no idea of the enormous sums of money which have been spent and are now a-spending on the improvement of harbor facilities. The competition between the ports of the countries of Europe is tremendous. Everywhere the works planned and building are almost of stupendous size. Italy, France, Germany, Holland, Belgium and England are spending vast amounts. In some of these States the general government mainly does the work, as in France and Germany; in others, it is divided, the general government taking a part of the load as in Italy, Holland and Belgium, while in England everything is done by private or corporation enterprise with little or no assistance from the State.

Go to London or Liverpool and see the miles of quays and acres of docks built by private capital and learn from them how wise has been this vast expenditure. Think on the Clyde and the Tyne, how from insignificant streams they have become the bearers of a mighty commerce. Again consider Manchester and the titanic work she is pushing through in the shape of a canal thirty-five and one-half miles long which will enable vessels drawing twenty-five feet of water to come to her docks after overcoming an ascent of sixty feet.

That these works are no child's play will be shown by a few figures. Take first the Manchester canal: It is thirty-five and one-half miles long, the minimum width at the bottom is 120 feet for a length of thirty and one-half miles, and 170 feet for the remaining five miles. The average width at the water level is 172 feet. The minimum depth is 26 feet. These figures give a total excavation of 30,000,000 of cubic yards for the trunk of the canal, provided that in no place does the ground along its sides lie higher than the surface of the water. But no consideration is made of the excavation for docks or locks. The water surface of the docks is 133¾ acres, all to be dug out of the earth. Of the locks there are fifteen:

1	600	feet long by	80	feet wide.
4	600	"	65	"
1	600	"	45	"
1	400	"	45	"
1	350	"	50	"
4	350	"	45	"
1	250	"	45	"
1	229	"	42⅗	"
1	150	"	30	"

To carry on this work requires 100 steam excavators, 173 locomotives, 194 steam and other derricks, 182 portable and other steam engines, 209 steam pumps, 6,300 cars, 59 pile-drivers and 223 miles of temporary railway; 16,361 men and boys, and 196 horses are employed. Of coal about 10,000 tons are used every month, and of cement about 8,000 tons or 44,000 barrels of 400 pounds each. I have been

unable to find any estimate of the cost of the work, but I am sure that I shall be well within the mark when it is put at $50,000,000.

The relative situation of Manchester and Liverpool is very similar to that existing between Philadelphia and New York. Manchester, like Philadelphia, is essentially a manufacturing place. Liverpool, like New York, is commercial. All of Manchester's business was done through Liverpool, as almost all of Philadelphia's is done through New York. The transportation between Manchester and Liverpool, as between Philadelphia and New York, is mainly by rail. Rail freight charges were oppressive, so the Manchesterians rose and said they would stand that sort of thing no longer; and proceeded to make a canal and to render themselves independent of Liverpool, and to do their own shipping.

Let us turn now to Glasgow and see what she has done with the Clyde, which, in the middle of the last century, was so insignificant a stream that it could be forded twelve miles below the city. From 1770 to June 30, 1890, there had been spent on the improvement of the Clyde $60,000,000 in round numbers. Much material has been scoured from the bed of the river through the agency of dykes, training walls and other works, and in addition to this, over 36,000,000 cubic yards have been removed by dredging. Instead of a petty stream, across which one could almost walk dryshod, there is now a channel through which vessels drawing twenty-four feet can pass at any stage of the tide. It may also be mentioned that the revenues accruing from these enormous expenditures have been most satisfactory, as they amount to $40,000,000 in round numbers, or sixty-six and two-thirds per cent. on the investment, which may be regarded as an excellent interest in a land where the prevailing rate is from three and one-half to four per cent.

[*To be continued.*]

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, February 16, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 16, 1892.

Dr. W. H. WAHL, President in the chair.

The Treasurer made the following report for the year 1891:

Cash on hand January 1, 1891,			$97 33
Received:			
By initiation fees,		$18 00	
Dues, 1890,	$6 00		
1891,	138 00		
1892,	2 00		
		146 00	
			164 00
			$261 33
Expended:			
Printing by-laws,		$12 99	
Addressing and postage,		31 50	
Printing for secretary,		18 75	
Envelopes and postage for treasurer,		3 94	
Friedlander's bill,		62 30	
			129 48
Cash on hand January 1, 1892,			$131 85
Outstanding dues, 1890,			$2 00
dues, 1891,			14 00
initiation fees,			2 00
			$18 00

The resignation of Dr. Persifor Frazer was read and accepted.

A number of bills, the contraction of which had already been authorized by the Section, were presented, and on motion it was voted that the Treasurer be authorized to pay them.

The Treasurer also presented a bill for expenses incurred in binding and in preparing for distribution among the members the copies of vol. iii, 1891, of the Proceedings of the Section. The President explained that these expenses properly belonged to the Section rather than to the Institute and on motion the payment of the bill was authorized.

Dr. E. H. Keiser gave an account of an investigation upon the composition of the explosive copper and silver compounds of acetylene. The paper will be published at length subsequently. The results obtained are in brief as follows: When pure acetylene is conducted into an ammoniacal solution of silver nitrate, the yellowish white precipitate which is formed has, when dried, the composition represented by the formula C_2Ag_2. It may in fact be regarded as acetylene in which both hydrogen atoms have been replaced by silver. The formula that has generally been adopted for this substance is $C_4H_2Ag_2O$. But such a compound contains only 83·71 per cent. of silver, whereas in three specimens of the substance prepared by Dr. Keiser the quantity of silver found was 89·32, 89·44 and 89·60 per cent. The formula C_2Ag_2 requires 89·9 per cent. silver. That the compound contains no hydrogen was shown by exploding a weighed quantity of it in a glass tube which had been exhausted with an air-pump; no hydrogen was obtained.

A study of the compound formed by acetylene in ammoniacal cuprous chloride showed that it was similar in composition to the silver compound, although in this case it was much more difficult to obtain the substance perfectly free from water. Analyses showed that the composition of the substance after it had been dried in a vacuum over sulphuric acid, agreed very closely with what would be required by the formula $C_2Cu_2.\frac{1}{2}H_2O$. The investigation will be continued.

The paper was listened to with close attention by the members present, and was followed by a number of questions and comments.

Dr. Bruno Terne followed with a paper, entitled "Notes on Iron in Bone Black." It was of special interest in connection with the application of bone black in sugar refining, and was discussed by the author and Dr. S. C. Hooker, the latter from the standpoint of an expert in sugar refining. Dr. Hooker stated that in cases where the percentage of iron reached a sufficiently high limit, it would be imparted to the sugar solution rather than abstracted from it, and hence such bone black would do harm rather than good. He also stated that sugar itself in solution has the power of dissolving iron, hence a further reason for the importance of eliminating iron in the manufacture of bone black.

Dr. Terne's paper was referred for publication in the *Journal*.

The Section then adjourned.

WM. C. DAY, *Secretary*.

ANALYSIS OF "EGGIO:" A PREPARATION OF THE YOLK OF EGGS.

By Charles S. Boyer.

[*Read at the stated meeting of the Chemical Section, January 19, 1892.*]

About a year ago I had occasion to make several analyses of "eggio"—a preparation of the yolk of eggs. Aside from the researches on pure egg yolk, I was unable to find any published analysis of the commercial product, and it may be of interest to place on record the results of my analysis. The ingredients for which the eggio was examined were water, ash and fatty acids, these being the only constituents of value in the dressing of fine leathers, for which purpose most of it is used.

The method which I used was as follows: Two to four grams of the eggio were dried in a weighed platinum dish for two to four hours at 110° C. and weighed, the loss being regarded as water. In order to facilitate the drying, a weighed quantity of coarse, ignited sand, or small pieces of infusible glass, was spread over the bottom of the dish. This dry residue was then ignited at a red heat and the resulting ash was calculated as mineral matter. The ash was light gray to white in color and was tested qualitatively for lime, but in no case was any found.

For the fatty acids, ten grams of the eggio were placed in a flask of about 350 cc. capacity and 150 cc. of ether poured over it. The flask was then connected with a reflux condenser and heated on a water-bath for two hours, being shaken every now and then to break up the white albuminous mass which collected in the bottom of the flask. The solution in the flask was allowed to cool and 50 cc. of the supernatant liquid removed by a pipette, replaced by 50 cc. of fresh ether, and the flask again heated for one hour, with frequent shaking as before. The flask was then allowed to cool and the clear yellowish liquid drawn off and added to the 50 cc. previously withdrawn. The contents in the flask were twice washed with ether and the ethereal layer added

to the first. This ethereal extract was placed in a flask and a portion of the ether distilled off. The solution was then placed in a weighed platinum dish and the remainder of the ether driven off on a water-bath. The residue in the dish was dried in an air-bath at 105° C., to expel any adhering water, and weighed.

The method was tried on a sample of fresh egg yolk and yielded 20·00 per cent. fatty acids, while in König's *Nahrungs- und Genussmittel* the percentage of fatty acids in pure egg yolk is given as 20·3. I, therefore, concluded that the method was sufficiently accurate for technical purposes.

As a result of the analyses of five samples of different lots of eggio by the above method, I obtained the following results:

	I. *Per Cent.*	*II.* *Per Cent.*	*III.* *Per Cent.*	*IV.* *Per Cent.*	*V.* *Per Cent.*
Water,	55·64	56·81 56·06	56·91 56·45 56·79	54·20	53·75 53·62
Ash,	11·73 11·80	19·25	9·46 9·47	13·67	16·35
Fatty acids,	14·66	—	—	16·00	15·23

In order to compare these results with those found for pure egg yolk, I give the following analyses, the first from König's *Nahrungs- und Genussmittel* and the second obtained by the writer with the above method.

	I. *Per Cent.*	*II.* *Per Cent.*
Water,	51·8	53·72
Salts,	1·0	—
Fatty acids,	20·3	20·00

By comparing these values with those above, it is found that commercial eggio contains from two to five per cent. more water, and three and one-half to six per cent. less fatty acid, than are found in pure egg yolk. The salts are sodium salts added in order that the eggio may be preserved from putrefaction.

As soon as time will permit, I hope to be able to communicate the exact composition of the ash of eggio, which I think will be of value in supplementing the above partial analysis of this product.

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, February 2, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 2, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty members and visitors.

The minutes of the previous meeting were read and approved.

The Secretary and Treasurer reported the issue of the first volume of the Section's *Proceedings*, and the cash balance on hand in the treasury.

The Committee on Admission reported one election to membership since last meeting, and one nomination was referred to them.

Resignation of membership from Prof. Henry Crew was accepted with regret.

The Chair announced the receipt of the first number of a new and promising French electrical journal, *L'Industrie Électrique*, edited by E. Hospitalier; the unavoidable postponement of Mr. Tesla's lecture in the Institute course, and of his later appearance before the Section; and the time-limit for papers read before the Section, with its possible extension.

Mr. Carl Hering described some details of the plant for power transmission at Niagara, some features of the Frankfort Electrical Exhibition, and Burton's process of electric forging, illustrating his remarks with lantern pictures.

Mr. Wm. S. Aldrich showed the results of some experiments upon the tractive force exerted on the core of a double-coil solenoid.

Prof. Houston's paper on "Cerebro-Radiation" was deferred till next meeting.

Several queries from the Question-Box were answered, and others evoked considerable interesting discussion.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

AN EARLY CONCEPTION OF THE MAGNETIC FIELD.

By Prof. Edwin J. Houston.

[*Read at the stated meeting of the Electrical Section, January 5, 1892.*]

It may interest the members of the Electrical Section to know, that as early as 1668, Robert Boyle, the eminent physicist and chemist, published, concerning the magnetic field, exceedingly advanced ideas which closely resembled the modern ideas of magnetic flux and lines of magnetic force.

Boyle's publication, so far before the time of Faraday, shows the exceedingly advanced position he must have occupied at that early date, as a thinker and investigator in physical science.

Boyle was an indefatigable worker, and a voluminous writer, both in the domain of physics and chemistry, as well as in that of medicine. He taught that absolute rest had practically no existence even in bodies in apparent rest, since there existed in such bodies what is called an intestine motion of their particles. He also had original notions of what was called, in his time, effluvia, and it was in connection with these so-called effluvia that he advanced an explanation concerning the magnetic action of the loadstone, which bears a remarkably close resemblance to the modern ideas of a magnetic field and lines of magnetic force.

The quotation referred to is from the second of two essays "Concerning the Unsuccessfulness of Experiments" published in 1668. In these essays he has been pointing out the necessity for care in conducting scientific experiments, and urges, that the failure to experimentally reproduce any natural phenomenon should not necessarily call in question the accuracy of the first observer of such phenomenon, until all the sources of error that might have led to obscuring or vitiating it had been eliminated. In this connection he cites, in a quaint manner, some of the

numerous experiments that he had been led to try on the assertion of well-known scientific men, but in which he failed to obtain the results alleged to have been observed. He describes in this connection the magnetization produced by touching a steel knife-blade to the armed pole of a loadstone, as resulting in different polarities according to whether the point of the blade is drawn towards or from the equator of the loadstone.

I will quote Mr. Boyle's remarks in full in this connection:

"If on either of the Extremes or Poles of a good armed Load-stone, you leisurely enough, or divers times, draw the back of a Knife, which has not before receivd any Magnetick influence, you may observe, that if the point of the blade have in this affriction been drawn from the middle or Æquator of the Load-stone towards the Pole of it, it will attract one of the Extremes of an equilibrated Magnetick Needle; but if you take another Knife that has not yet been invigorated, and upon the self-same Extremity or Pole of the Load-stone, thrust the back of the Knife from the Pole towards the Æquator or middle of the Load-stone, you shall find, that the point of the Knife has, by this bare difference of Position in the blade whilst it past upon the Extreme of the Load-stone, acquired so different a Magnetick property, or Polarity, from that which was given to the former Knife by the same Pole of the Load-stone, that it will not attract, but rather seem to repel or drive away that end of the Magnetick Needle which was drawn by the point of the other Knife. And this improbable Experiment not only have we made trial of, by passing slender Irons upon the Extremities of armed Load-stones, the breadth of the whose Steel-caps may make the Experiment somewhat less strange, but we have likewise try'd it by affrictions of such Irons upon the Pole of a naked terella, and we have found it to succeed there likewise. How strange soever it may seem, that the same point or part of the Load-stone should imbue Iron with contrary Properties, barely as they are, during their passing over it, drawn from the Æquator of the Load-stone, or thrust towards it. But whether, and how far this Observation insinuates

the operations of Load-stone to be chiefly performed by streams of small particles, which perpetually issuing out of one of its Poles, do wheel about and re-enter at the other; We shall not now examine (though this seem one of the most likely Phænomena we have met with, to hint a probable Magnetical Hypothesis) contenting ourselves to have manifested by what plainly appears, how much influence a circumstance, which none but a Magnetick Philosopher would take notice of, may have on an Experiment."

Mr. Boyle had obtained an insight into the actions which occur during magnetization, far beyond that of his contemporaries. This fact appears to be clearly indicated by the above statement as to what he believed to be the actual operation of the lodestone; namely, that it produced magnetization by means of streams of small particles coming out of one pole and re-entering at the other pole. Change the phraseology but a trifle and leave the ideas as expressed, and we have at this early date a fair idea of the modern notion of magnetic flux.

Boyle's notion seems to have been that when other bodies were brought into this magnetic stream, they became endowed with magnetic properties by the particles or corpuscles forming the stream, passing through them, just as we now explain magnetization by the passage through a magnetizable substance of the lines of magnetic force.

In a later paper, published in 1669, on "The Absolute Rest of Bodies," he asserts that the particles even in exceedingly dense substances that are apparently at rest, are, in reality, in rapid motion. He urges that although such motions cannot be seen, yet they must exist, and cites as a proof of such assertion, the following experiment, which I will give in Mr. Boyle's language:

"I briefly answer (for I would not here repeat what I have elsewhere said on this point) by this clear Experiment, that though your Eye can discern no change in the outward and visible, much less in the more latent and internal Corpuscles of Iron: a vigorous Load-stone by passing along its Axis from one Pole of the Stone to the other, and back again, yet the Texture of the Iron is by that action of the

Load-stone so changed, that it acquires, and then loses those admirable Qualities we call the Attractive and Directive virtue or faculty peculiar to Magnetick Bodies."

And further on, in the same paper, in speaking of the well-known fact that a mass of steel when allowed to stand in an upright position for some time on the earth, is endowed with magnetic properties, he ascribes these properties to the action which the streams of corpuscles exert on it.

"To this purpose I shall only observe to you, that though a Bar of Iron having one of its ends held perpendicularly, and at a fit distance to the Lilly or Northern point of the Mariner's Compass (I mean that which points towards the North), it will, as I elsewhere mention, drive it away towards the East or West: and if this same lower end of the Bar of Iron be put into a contrary posture, it will presently lose its temporary magnetism, as I elsewhere declare. Yet if this Bar be very long kept upright in a Window or other convenient place, then, as some late Magnetickal Writers will tell you, it will have acquired a constant and durable Magnetick power. Which is a phenomenon which makes exceedingly for our present purpose, since it hence appears both that the Air together with the magnetical effluvia of the Earth that it receives in its Pores, is able without outward force to work durable changes in so solid a Body as Iron, and that the motions of the internal Parts, for these are requisite to change the Metal's Texture, are performed with a wonderful slowness, since the Bar must be very long exposed to the air, perhaps before it acquires any durable magnetism at all, but at least before it acquires so vigorous and fixt a magnetism as by this means it may attain to."

In another paper on "The Nature, Properties and Effects of Effluvia," reproduced by Shaw at a later date, in vol. i, p. 411, of the Philosophical Works of the Honourable Robert Boyle, Esq., 1725, Boyle writes as follows:

"To clear this matter, I caused some needles to be hermetically sealed up in glass pipes, which being laid on the surface of the water, whereon they wou'd lightly float, the encluded needles did not only readily answer to the load-

stone externally applied, tho' a weak one, but comply'd with it so well that I cou'd easily lead, without touching it, the whole pipe to what part of the surface of the water I pleased. I also found that by applying a better load-stone to the upper part of the seal'd pipe, with a needle in it, I cou'd make the needle leap up from the lower part, as near to the load-stone as the interposed glass wou'd give it leave. But I thought it more considerable to manifest, that the magnetical effluvia, even of such a dull body as the globe of the earth, wou'd also penetrate glass. And this I attempted after the following manner. I took a cylindrical piece of iron, about the bigness of one's little finger, and between half a foot and a foot long; having formerly found that the quantity of unexcited iron forwards its operation upon excited needles; and having hermetically seal'd it up in a glass pipe, but very little longer than it, I suppos'd that if I held it in a perpendicular posture, the magnetical effluvia of the earth, penetrating the glass, wou'd make the lower extreme of the iron answerable to the North Pole; and, therefore, having applied this to that point of the needle, in a dial or sea-compass, which looked towards the North, I presum'd it would drive it away, which accordingly it did. And having, for further trial, inverted the included iron, and held it in a perpendicular posture, just under the same point, that extreme of the iron rod, which before had driven away this point, being, by inversion, become a South Pole, attracted it; from which sudden change of the poles, merely upon the change of the situation, it also appeared that the iron owed its virtue only to the magnetism of the earth; not that of another load-stone which wou'd not have been thus easily alterable."

I need not call your attention to the marked similarity between the manner in which Boyle conceives magnetic induction to take place, and our modern notions concerning the same phenomenon. His streams of magnetic effluvia correspond exactly in direction and action to our present conceptions of magnetic flux and lines of magnetic force.

Coming now to the time of Faraday, we find in a paper, published by Faraday in the *Philosophical Transactions*,

in 1852, the following: "From my earliest experiments on the relation of electricity and magnetism, I have had to think and speak of lines of magnetic force as representations of the magnetic power, not merely in the points of quality and direction, but also in quantity." * * *

"A line of magnetic force may be defined as that line which is described by a very small magnetic needle, when when it is so moved in either direction correspondent to its length, that the needle is constantly a tangent to the line of motion." * * *

"These lines have not merely a determinate direction recognizable as above, but because they are related to a polar or antithetical power, have opposite quantities or conditions in opposite directions. These qualities, which have to be distinguished and identified, are made manifest to us, either by the position of the ends of the magnetic needle, or by the direction of the current induced in the moving wire."

As to the direction of the lines of magnetic force, Faraday, as is well known, regarded them as coming out of one pole of the magnet and passing in at the other pole, and referred to this in a paper printed in the *Proceedings of the Royal Institution*, on the 23d of January, 1852, as follows:

"The lines of force already described will, if observed by iron filings or a magnetic needle or otherwise, be found to start off from one end of a bar-magnet, and after describing curves of different magnitudes through the surrounding space, to return to and set on the other end of the magnet."

There is, of course, a danger in quoting from an early writer, of reading into the quotation a significance that it could not have had, save by the light of subsequent researches. It is far from my purpose, or desire, to belittle the researches of Faraday. I merely desire to show by a comparison of the writings of these two philosophers, the remarkable advance that Boyle had made as to the manner in which a magnet acts.

In the above quotation from Boyle it must be remembered that Boyle referred to certain effluvia which he believed were given off by the magnet. His conception, however,

of these particles coming out at one pole and reëntering the other, and his mentally endowing streams of such particles with polarity, or the possession of opposite properties in opposite directions, was certainly a remarkable advance for his times and shows how far he was beyond his contemporaries.

It is possible that other writers before the time of Boyle, or between his time and that of Faraday, may have expressed somewhat similar ideas. I merely call your attention to the quotations from Boyle as showing the remarkable grasp of magnetic phenomena possessed by this early philosopher.

NOTES ON ELECTRO-MAGNETIC MACHINERY.

[SECOND PAPER.]

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[*Read at the meeting of the Electrical Section held January 5, 1892.*]

Electro-magnetic Reciprocating Mechanisms form a class rapidly developing in application to work requiring controlled reciprocation with definite variations of the energy of the stroke. These two questions—the kinematics and the dynamics of this mechanism—have been met in what may be styled the *multiple-coil solenoid.* It will be of interest to lead up to the form developed in the Van Depoele machine—from the electro-magnetic point of view. The several steps do not always (in some cases very rarely) coincide with the evolution of the idea from its earliest inception in the mind of the inventor. But, examining how a given electro-magnetic mechanism could have been evolved—finding how it came to be as it is—may be of service in the development of new forms—quite different in principle and application, yet worked out in more or less accord with the laws of kinematic synthesis; that is, the development of a machine for definite work and certain required motions.

Multiple-coil Solenoid Mechanisms require to be energized by currents of variable potential, producing variable and shifting magnetic fields of force, which may be caused to act in conjunction with or in opposition to each other. These potential variations in the respective coils may be produced and controlled by adjustable external resistances, or by one or more rotating brushes around the commutator of a dynamo.* In either case, variable undulating (pulsating), or alternating currents, may be produced from a source of constant potential. The loss of energy in adjustable resistance being very objectionable, the rotating-brush mechanism is used—fulfilling the fundamental purpose. This is to convert the electrical energy of a continuous-current machine, rotating at its most efficient speed, into undulating currents having any desired rapidity of succession, corresponding to the number of reciprocations of the plunger core working as a piston within the solenoid. The kinematic question is therefore met by fulfilling the conditions of comparative motion in mechanism—(Willis) the directional relation between the rotating brush and the reciprocating plunger, and their velocity ratio of movement. And it satisfies another condition, stated by Reuleaux, in that the relative motion between the two elements is under constrainment, even if this is brought about by electro-magnetic stresses in the ether medium, rather than by the molecular stresses of rigid connecting links of a kinematic chain. The mechanics of this mechanism—the statics and dynamics of its own peculiar medium for the transmission of energy, show that the electro-magnetic forces of Nature can be compelled to do work. And the ether medium, with its induced electro-magnetic stresses, being as much a *resistant* body as more material mediums with their molecular resistance to change of form or of volume, constitute this combination an electro-magnetic machine, from an adaptation of the definition of Reuleaux, given in the former paper. The tubes of force of the magnetic field may change their *form* to a

* As in the Van Depoele Pulsating Electric Generator, United States Patent, No. 422,855, March 4, 1890.

very great degree, but they remain unaltered in *volume;* and, it is the resistance of the tubes of force to any change of volume, which answers as well for the performance of work or the transmission of energy or motion, as the resistance of a bar of rigid material to any alteration of its length or general form.* Also, examined in the light of Sylvanus P. Thompson's treatment of electro-magnetic mechanisms,† the one under consideration possesses the characteristic feature that it is a combination in which power is transmitted electrically along a wire, and made to produce, through its electro-magnetic combinations, certain mechanical motions.

The Single-coil Pulsating-current Solenoid is shown in *Fig. 1*, diagrammatically, in combination with the rotating brush *M*

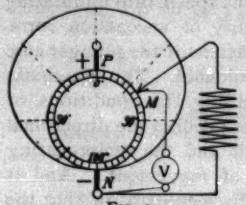

FIG. 1.

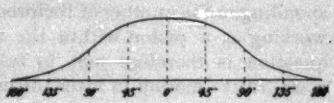

FIG. 2.

Single-coil pulsating-current solenoid mechanism, with ideal integrated curve of potentials.

and one terminal of the stationary brushes *N*, of the dynamo. What Sylvanus P. Thompson has called the integrated curve of potentials, being the total or integrated potential taken at each bar all round the commutator (by the indicated voltmeter connection) has been plotted in its simple *ideal* form, around the commutator in *Fig. 1*, and as referred to rectangular coördinates in *Fig. 2*.

It is the line-integral of the ideal (sine) curve of induction; and, any ordinate represents the total induction from

* Compare Rankine, *Machinery and Millwork*, chap. iv, sec. viii, art. 207. Thurston, Introduction to *Kinematics of Machinery*, Van Nostrand's Science Series, No. 54, p. xi. Kennedy, *Mechanics of Machinery*, chap. i, sec. 1.

† *The Electrical World*, 1891, January 17th; also, in his work on *The Electro-magnet*.

the fixed brush *N* up to that point of the rotating brush *M*. With the rotation of the brush *M*, there is produced a variation of potential through the solenoid coil, a corresponding undulation of current strength and so a variation of ampère turns and a rise and fall of the intensity of magnetization of the solenoid core. This causes the plunger to be drawn into its coil with variable energy, according to the laws of the magnetic circuit, by which it continually so tends to place itself that it shall be in the field of maximum induction at any one time. The action is only in one direction—after reaching the maximum, at 180°, the plunger gradually falls out of the coil by its own weight, or is retracted by a spring to its original position. If the rotating brush is held at any position around the commutator, the plunger

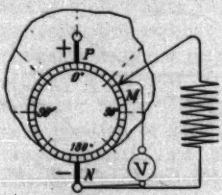

FIG. 3.

FIG. 4.

The single-coil electro-magnetic mechanism, with real integrated curve of potentials.

will remain in its corresponding position for that point; being in more or less stable equilibrium between the electro-magnetic stresses of the ether medium, and the force of gravity or of a retracting spring. It would be possible to give a slight oscillation to the plunger in this position, as it is under the action of the contractile energy of the tubes of force, which is a property that the current has conferred on the ether medium surrounding the coils; by this its tubes of force develop a marked tendency to shorten in the direction of their length, and spread out in directions at right angles to their length. The integrated curve of potentials represents an entirely ideal condition of the cycle of operations; and does not indicate that the intensity of magnetization will proportionally vary in more than a quite

general way. The several resistances in the path of the magnetic circuit—that of the air gap and of the iron portion—as well as the counter-electromotive force dependent on the speed of reciprocation, and the movement of the plunger into and out of the field of force, will continually vary the resultant effect of the variable field of force. It becomes then, rather difficult to plot exactly the real flow of magnetic stress along the corresponding positions of the plunger. It belongs to the class of intermittent mechanisms; and, like single-stroke devices, requires reactive forces to restore it to its original position. From the point of view of electro-magnetic kinematics, it is a simple one-circuit (magnetic) mechanism, of constant direction (polarity) and varia ble intensity (of magnetization or of induction).

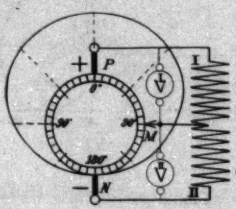

FIG. 5.

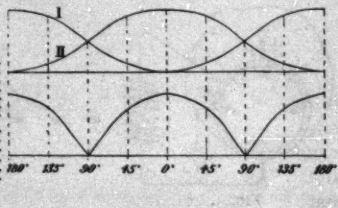

FIG. 6.

Two-coil pulsating-current solenoid mechanism.

Figs. 3 and *4* show the *real* curves of the distribution of potential, taken with voltmeter, as indicated, and with no other external circuit, from a small separately-excited motor, run as a dynamo, with constant field.

The Two-coil Pulsating-current Solenoid has its outer terminals connected to the fixed brushes, *P* and *N*, as in *Fig. 5*, and the inner join of the same coils to the rotating brush *M*. The resultant action of the two fields of force of the coils, may be quite different: (*a*) according to whether the two coils are connected up to operate in conjunction with each other, as two parts of one coil, called a differential coil-and-plunger mechanism, by Sylvanus P. Thompson; or (*b*), when the two coils are connected up in opposition to each other, producing variable

electro-magnetic stresses working against each other. In the former case the mutual actions of the two solenoid coils are reciprocal, the energizing effect of one of the coils increasing from zero to a maximum, while the other decreases from a maximum to zero, as the rotating brush is moved around the commutator a half turn, indicated in a general way by the ideal curves of integrated potential, the upper curves of *Fig. 6*. This ideal cycle of operations being completed shows two nodal points—positions of electro-magnetic equilibrium—when the plunger is under the action of balanced electro-magnetic stresses. This equilibrium is more or less stable, depending upon whether the two coils work with or against each other. The lower curves, *Fig. 6*, represent what may be termed the effective electro-motive force, being found by taking the differences of corresponding ordinates of the upper curves. The portions between the nodal points are really of opposite sign, representing a reversal of the resultant effect of the variable magnetic fields. The plunger, on passing the nodal point, as a position of zero pull, goes more completely into the range of action of the increasing magnetic field and out of the decreasing field of the other coil. The combination of the two coils acting in conjunction, results in an almost constant magnetization of the plunger, so that it has generally a steady pull and a regular movement, in which it follows the movement of the field of maximum induction of the solenoid coils, determined by the rotating brush *M*. It is a double-acting mechanism, giving two controlled reciprocations of the plunger for one rotation of the brush *M*. For producing hammer blows, regulating switches may be used to vary the intensity of the magnetic field, according to the location and character of the work. The electro-magnetic conversion of continuous circular into reciprocating rectilinear motion may be accomplished with equal facility and regularity, for almost any intervening distance, an advantage not possessed by its somewhat analogous mechanical (kinematical) equivalents of finite connecting rod, nor of the so-called infinite connecting rod.

Multiple-coil Pulsating-current Solenoids admit of varying

the power stroke, as in hammer-blows, to meet requirements of the work, while there is a very light return stroke to prevent excessive wear and tear of the machine. By winding the solenoid coils in three or more sections, of equal resistances, longitudinally disposed, and connecting the two or more forward sections in parallel with the supply wires and the back section singly—the current through this section will be correspondingly less than that through the other section with joint resistance in parallel.* This arrangement will therefore throw the preponderance of power in the forward stroke.

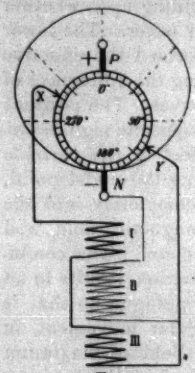

FIG. 7.

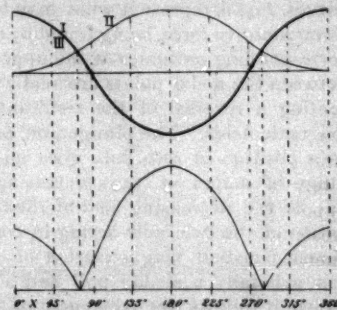

FIG. 8.

Three-coil pulsating- and alternating-current solenoid.

The Three-coil Pulsating- and alternating-current Solenoid, with two rotating brushes, is shown in *Fig.* 7. Another but similar diagram,† was explained at the close of the former paper. At the same time that there is a controlled reciprocation, the combination of the pulsating current through the fine-wire coil *II*, with the alternating current through the coarse-wire coils *I* and *III* gives a heavy

* Van Depoele's method, set forth in United States Patent, No. 422,855, March 4, 1890.

† From *The Electrician* (London). Vol. xxviii, Nov. 6, 1891, p. 10.

power stroke in the forward direction and a light return stroke. *Fig. 8* shows this in the form of the potential cycle, the light-line curve *II* being the ideal curve of the integrated potential for the pulsating current of coil *II*, and the heavy-line curve *I—III*, that for the alternating-current coils *I—III*. The lower curve represents, as in *Fig. 6*, the differences of the corresponding ordinates of the upper curve. There are several pecularities of these curves; and, though entirely ideal, may serve to aid us in forming some notion of the real distribution of electrical energy in the solenoid coils. The nodal points are both on the return-stroke end of the plunger-cylinder, encasing the mechanism. The long ordinate at the centre shows a very heavy power-stroke forward, while the short ordinates at the ends show light return strokes, with more or less of a cushioning effect. The action of the energizing polarizing coil *II*, shows how its pulsating current—in the one case causes a very rapid increase of the resulting maximum induction, and in the other, at the end of the stroke, having no effect, as it simply rises and falls between zero and a maximum. The alternating current passes from maximum to maximum in opposite directions, and cuts the pulsating curve nearer the weak end of each case. The iron core, under the chief energizing coil *II* is not electro-magnetically equivalent to a permanent magnet core, for it is now *variably* energized in one direction, at about the proper points. But, in the latter case, its constant magnetic field would seriously interfere with this very arrangement of the two kinds of currents to produce maximum forward stroke. By reversing the connections of coil *II*, the other stroke will be a maximum. More than three coils may be used, and the respective positions of the pulsating and of the alternating-current coils may be reversed, or otherwise arranged to suit the requirements of the work.

Derived Mechanisms from Multiple-coil Solenoids admit of many industrial applications. For instance, it gives at once a kind of electro-magnetic *dash-pot*, buffer, cushion, brake or clutch for reciprocating movements. And this possesses capabilities of adjustment not usually found in rigid or

even flectional-element mechanisms, of changing quickly and surely the intensity of the tractive force as well as the position of its static equilibrium. Periodically varying the speed of rotation of the brush *M* will result in corresponding variations in the rate of reciprocation, with or without changing length of stroke. The length of stroke may be changed by auxiliary and solenoid coils. On the other hand, the speed relations may be maintained constant, and the power stroke varied at will, or both may be varied to any desirable extent. Another modification, which would produce multiple nodal points, would give multiple-reciprocation mechanism (*reduplication*, of Willis), obtaining four, eight, or more reciprocations for one rotation. For the stress nodal points indicate the electro-magnetic dead centres, of which there must be as many as the number of reciprocations desired. So with electro-magnetic *cams*—the stroke of the plunger may be made to follow any given law of cam curves or spirals, as the Archimedian or logarithmic, by simply controlling the rotating brush *M*, according to the same law. And the stop, dead and change points of ordinary cam plates may be controlled with equal facility by this electro-magnetic combination. Electro-magnetic *ratchet* mechanisms, where there is no special return or reversal of motion, may be equally developed from the solenoid mechanism, chiefly of the multiple-coil types, with the coils connected up in series, as in the port-electric and other electro-magnetic package-carrying devices.

The Cycle of Operations of Electro-magnetic Machinery possesses features characteristic of the ether medium employed. The fundamental cycle is necessarily that of the physical condition of the medium at each point; following this are the energy cycles of the medium and throughout the mechanism, and the kinematic cycle of the mechanism of transmission. Or, perhaps more generally, the transformation or conversion cycles of the medium would be considered first, then the transmission cycles of the intermediate mechanism and machinery, through which the transformation cycles indicate the performance of useful work by the so-called mechanical forces of nature. Each of these ele-

ments of the complete cycle—the ether medium and the mechanism of transmission—may again be considered, especially with reference to the *mechanics* of the elements involved; that is, the mechanics of the electro-magnetic stresses of the ether medium as of a *resistant* body,* and the mechanics of the molecular stresses of the material elements of the electro-magnetic machinery. In considering in a somewhat analogous way, the mechanics of the medium and the mechanism of the steam engine, Prof. R. H. Thurston† has extended the point of view along the lines of Rankine, and thus groups under the heading of *Mechanics:*

(1) *Statics*, treating of the relations of forces in any system or medium, when no motion results from their action.

(2) *Kinematics*, treating of the relations of motion simply.

(3) *Dynamics*, or kinetics, treating of the action of forces accompanied by motion.

(4) *Energetics*, treating of the transfer, transformation, transmission or modification of energy, under the action of forces, from one mode of manifestation to another, and from one body to another.

Examining, for a moment, the application of the above to electro-magnetism, with ether as the medium, it will be found that the lines have already been mathematically laid out by Maxwell in the direction of electro-statics, electro-kinematics and electro-dynamics, resting somewhat anteriorly upon Faraday's researches and posteriorly upon Hertz's experiments. We have noted the statical action of the electro-magnetic stresses, when under more or less stability of equilibrium, as in the solenoid mechanisms; the kinematic conception of the ether mechanism, as stated in the former paper, has served fairly as a working hypothesis, in lieu of a better; while the dynamical conception has shown the ether to be a suitable medium for the transfer or transmission of energy accompanied by definite motions. In order to investigate the complete cycle of operations of

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* *Resistant* in the sense of acting as a body constantly maintaining its volume while undergoing any kind of alteration of its volume-form.

† *Manual of the Steam-engine*, Part I, pp. 298 and 304.

an electro-magnetic mechanism, the whole of its mechanics should be developed—for the ether medium and for the machine elements. This, therefore, involves the *energetics* of the medium, giving the etheric energy cycle (electro-dynamic), as we have for the steam engine the thermo-dynamic cycle. And, the energetics of the ether medium may come to be studied by autographic records of its energy cycle, bearing the same relation to the electro-magnetic mechanism that the indicator card does to the distribution of energy in the steam-engine mechanism.

Differential Electro-magnetic Mechanisms may consist: (1) of variable-speed or power (or both) combinations effecting their purpose by electro-magnetic action, not necessarily of itself differential; (2) of variable-action mechanisms having a differential effect brought about in the electro-magnetic stresses themselves. In the former case, the mechanism is inherently differential, whether controlled, operated or actuated electro-magnetically or pneumatically for instance; such would be a differential screw, pulley or other *mechanically* differential mechanism. In the second case, we have the two-coil solenoid; the solenoidal electro-magnetic balance, and the dynamotor balance shown later, the differential action being due to a preponderance of a simple or of a resultant magnetic field over a surrounding field or fields.

Epicyclic Gear-wheel Mechanisms are differential in character, as may be seen by referring to *Fig. 9*. The motor armature M_1 and gear-wheel A are secured to a sleeve, loosely turning on shaft $P\,P$, and the motor armature M_2 and wheel B, similarly placed on shaft $S\,S$. Three principal combinations of these three elements of a simple kinematic chain are possible. (1) If the arms $X\,X$, connecting the shafts, are fixed—one machine will drive the other as a dynamo—the fields being supposed secured to the arms $X\,X$. (2) if shaft $P\,P$ is held in fixed bearings, field of M_1 stationary, and both motors set in operation, the arms $X\,X$ will carry combination around the shaft $P\,P$, when the motors revolve at different speeds. The arms $X\,X$ will turn around in a direction dependent upon the direction of rotation of the

motors, and at a speed proportional to the speed of the motors and the number of teeth on the wheels. When the wheels have the same number of teeth: (*a*) and the motors revolve at the same speed in the opposite direction, there will be no rotation of the arms; (*b*) motors revolve at different speeds, the arms will turn at a speed of half the difference of the motor speeds, and in the direction of the greater one. (3) If shaft *S S* is fixed, instead of *P P*, field of M_2 stationary, similar combinations will produce similar results in effecting the rotation of the arms. Several minor combinations are possible in each case, but the above serve to show

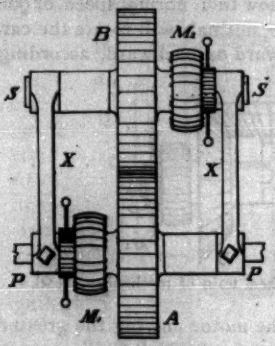

FIG. 9.

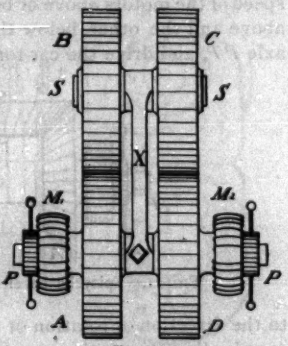

FIG. 10.

Epicyclic spur-wheel mechanisms, driven by electric motors.

the differential nature of this form of a simple epicyclic gear-wheel train.

In *Fig. 10* motion is communicated to the wheel *B* through the wheel *C* on same sleeve as *B*, and geared to *D* on same sleeve as motor armature M_2, loosely mounted now, on shaft *P P*. This is permanently mounted in bearings, and has no rotation, when the gear wheels *A D* and *B C* are of same size, and the motors M_1 and M_2 revolve at same speed in same direction. When the motors M_1 and M_2 revolve in the same direction at different speeds, the arm *X* (keyed to shaft *P P*) rotates at a speed equal to half the difference of the motor speeds.

In *Fig. 11* bevel wheels have been substituted for the spur wheels of *Fig. 10*, reducing the number; as the bevel wheel *B*, loosely sleeved on the arm *X* meshes with *A* and *D*, and so performs the mechanical functions of both the wheels *B* and *C*, of *Fig. 10*. The motors M_1 and M_2 are mounted as before, and cause no rotation to the arm *X* or shaft *P P* when they revolve in opposite directions at the same speed. When so revolving, at different speeds, they rotate the arm *X* at a speed of half their difference of speeds, in the direction of the greater. This is the fundamental form of the Edison epicyclic street-car gear. A slight alteration in the speed of the motors above or below their normal speed, or one above and the other below the normal, will rotate the car-axle *P P*, and drive the car forward or backward, according

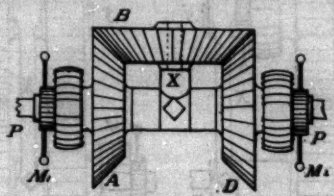

FIG. 11.—Epicyclic bevel-wheel train of mechanism.

to the direction of rotation of the motor having the greater speed. Sometimes the arm *X* and wheels *B C*, *Fig. 10*, are duplicated on the other side of the shaft, as in *Fig. 16*, which distributes the strains, but in no way changes the kinematical relations. A similar addition to *Fig. 11* is to extend the arm *X* and loosely mount fourth bevel wheel on it, between *A* and *D*. All of these are simply electrically-driven epicyclic gears.

Epicyclic Electro-magnetic Mechanisms may now be derived by substituting dynamotors (or double motors if needed) for the pair or pairs of gear-wheels. In *Fig. 12*, the dynamotor combination *C D* has been substituted for the two wheels *C D*, of *Fig. 10*, discarding motor M_2. For armature *D* being mounted on the same sleeve with *A* and *M*, and so driven by *M*, now operates as a dynamo, supplying current

to armature *C*. This is on same sleeve as wheel *B*. The dynamotor fields are secured to arm *X*. Therefore, while the motor *M* is run at a constant speed all the time, the dynamotor *C D* being then operated as a variable-speed dynamotor, the speed of *C* may be varied at will. As the fixed speed-relation between the gear-wheels *A* and *B* cannot change—an increase or decrease of the speed of *C* from the normal, will cause the arms *X X* to rotate the shaft *P P*, in the same way that *Figs. 9* and *10* would operate if the motor M_1 were run at constant speed while motor M_2 should

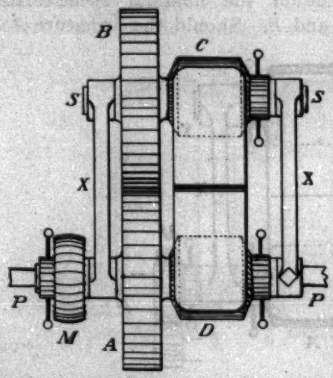

FIG. 12.

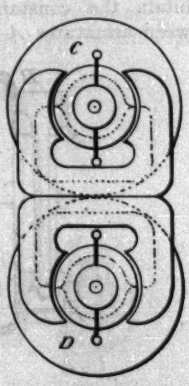

FIG. 13.

Combination of spur-wheels and dynamotor in an epicyclic train.

be varied as we have now supposed motor *C* to have been. *Fig. 12* might also have been derived from *Fig. 9* by putting in the dynamotor *C D* instead of the motor M_2. *Fig. 13* is a side view of the dynamotor of *Fig. 12*. This is yet a combination of mechanical and electro-magnetic elements. Drop the wheels *A* and *B*, giving form in *Fig. 14*.

Fig. 14 is the true electro-magnetic and epicyclic mechanism combined. The dynamotor fields are secured to the arms *X X*. The motor *M* driving it, tends to drive the armature *A* as a dynamo, but both *A* and *B* are connected up with the external circuit, either as a constant or a

variable-speed dynamotor. Therefore, if motor *M* runs free (open circuit) there is no rotation to the arms *XX*, while *A* and *B* are revolving all the time at a nominally fixed speed-relation.

(*a*) Now, upon operating *M*, as a motor, but against the rotation of *A* (and therefore, as a brake to *A*), the armature *A* will be slowed down, which will cause the field of the dynamotor and arms *X X* to rotate in the opposite direction of armature *A*, in order to continue cutting the lines of force across armature *A* at same rate as before, and so to maintain the constancy of the nominal speed-relation between armatures *A* and *B*. Should the armature *A* be

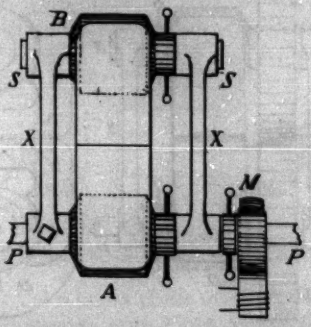

FIG. 14.—Epicyclic electro-magnetic mechanism.

slowed down till it stops, the dynamotor field will increase its speed of rotation till up to the former speed of its armature *A*, and will maintain that speed, still in the opposite direction, as long as armature *A* is held stationary, by the armature of *M*, on its sleeve, being now electro-magnetically clutched by its stationary field. Slowly releasing armature *A*, will cause it to react against its dynamotor field, tending to stop it; when armature *A* is once more free the arms *X X* are stationary again.

(*b*) By again operating *M* as a motor, but causing its armature to rotate in the same direction that it had been going when free, and increasing its energy gradually, it

will cause the armature *A* so to react upon its dynamotor field, as to continue to cut across the lines of force at same rate as before, which will therefore give a rotation of the dynamotor in the *same* direction as its armature *D*.

Besides controlling the motion of the dynamotor field (and so of its arms *X X*, and shaft *P P*), entirely by motor *M*, it may be partly controlled by regulating the external circuit supply to the dynamotor fields and armatures.

Fig. 15 is a double form of this mechanism, derivable from *Fig. 14*, by adding another dynamotor, or from *Fig. 12*, by substituting a dynamotor *A B*, for the gear-wheels *AB*. One or both of the dynamotors may be variable-speed

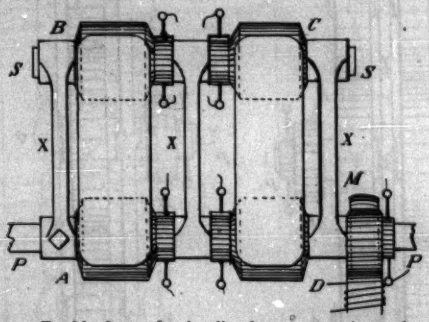

FIG. 15.—Double form of epicyclic electro-magnetic mechanism.

combinations; and one only or both may therefore be under control of the external circuit. The armatures *A*, *D* and *M* are all on same sleeve, loosely mounted on shaft *P P*. The armatures *C* and *D* are on same sleeve, loosely mounted on shaft *S S*. The operation is analogous to that of *Fig. 14*.

Fig. 16 is a double form of the gear wheel form of *Fig. 10*, and *Fig. 17* is a double form of the combination shown in *Fig. 12*.

Three-armature Dynamotors are shown in *Figs. 18* and *19*, the former having a two-branch magnetic circuit, and the latter a four-branch circuit. Either of these will serve for the combination shown in *Fig. 17*. All of the armatures of

either *Figs. 18* or *19* may be run: (*a*) as dynamos with electrical output of current; (*b*) as motors, with mechanical output of power; or, (*c*) one or more may be run as dynamos supplying current for the remaining armatures, as motors, in the same magnetic fields. The differential operation of the branch circuits *C* and *D* would result in no flux of lines across armature *Q*, when the fields of *C* and *D* were exactly

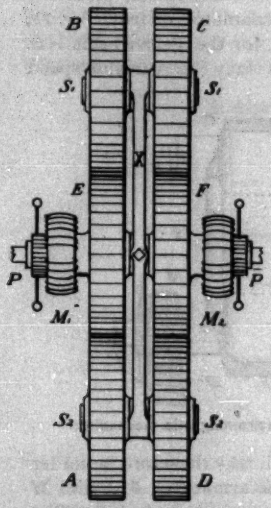

FIG. 16.

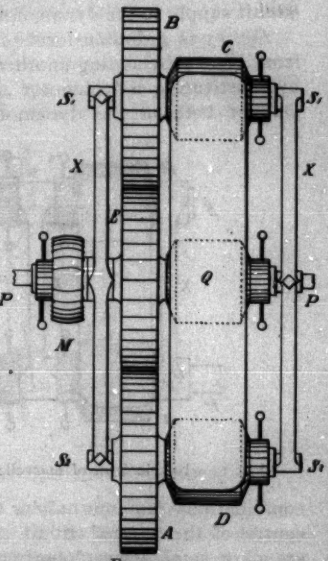

FIG. 17.

Double forms of epicyclic mechanisms, derived respectively from *Figs. 10* and *12*.

balanced. We have then electro-magnetic equilibrium, as formerly in the solenoid mechanism, and more or less stable, according to the character of the balanced fields of force. Moreover, there is constant air-gap resistance here, independent of the position of the balanced circuits, as was not the case with the differential coil-and-plunger mechanism. This eliminates the many disadvantages of the electro-magnetic

balance in the solenoidal form, and may give this type, or a modification, some useful purpose to fulfil as a measuring instrument. When there is an exact balancing of the magnetic flux from *C* to *D*, on each side, there will, of course, be no rotation of the armature *Q*. And when there is not a balance, it will either cause a rotation of the armature *Q* (if the dynamotor field is fixed), or cause an angular swing of the field (if the armature *Q* is held stationary). This swing of

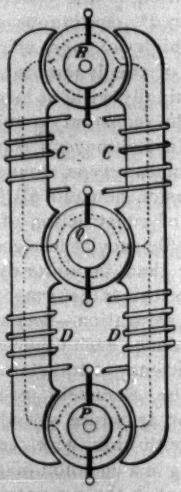

FIG. 18.

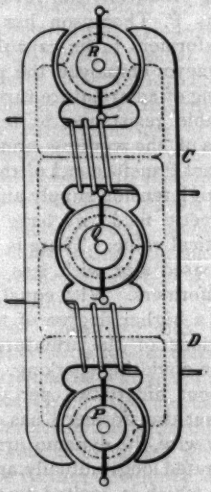

FIG. 19.

Three-armature dynamotors.

the field is somewhat analogous to the swing of the field of a dynamo when mounted in the form of the Brackett cradle dynamometer. Within certain limits the angular deflection is a measure of the torque.* Brackett states that if the counterbalancing effort of the spring balance or weights be removed, the field will perform a complete revolution and

* Used at the Stevens Institute of Technology, 1884, and described in the *Electrical World*, Jan. 5, 1884.

go on revolving, increasing its speed till it and the armature (practically) revolve together; when, of course, there is no work done but in overcoming internal and external friction. This action of the field and armature is analogous to that considered for the combinations of epicyclic mechanisms, *Figs. 14* and *15*.

The Efficiency of Dynamotor Transmission should approximate to that of the motor-dynamo transformers, the one being practically the reverse operation of the other. Sylvanus P. Thompson has considered* continuous-current transformers to be capable of a high average efficiency. Lahmeyer employed the principle of the dynamotor,† consisting of an armature turning nominally without load, as a variable resistance, to regulate the (constant) number of turns of the working armature. In Lahmeyer's constant-current transformer,‡ of the one-armature type, wound both for high tension supply and low tension demand, all in one magnetic field—we have a form of construction of high practical value. There is higher efficiency at less cost and decreased size, with less sparking than in motor-dynamo transformers. With equal excitation this transformer works with a higher degree of magnetic saturation—because the reactions of the armature coils balance each other, a condition obviating sparking. The efficiency of transformation is about ninety-two per cent. The Bernstein constant-current transformer§ has its motor armature wound with thick wire, the dynamo armature with thin wire, entirely separated longitudinally, and turning in a common magnetic field, which is excited by the current in the primary wire. Being a series-field, with primary field in series with the thick-wire coils of the magnet—the speed varies directly as the electro-motive force required, a peculiarity of some importance in certain work. Elihu Thomson's continuous-

* Paper before the International Electrical Congress, on "Constant Current Transformers," Paris, 1889. See *Electrical World*, Sept. 21, 1889.

† *Electrical World*, Oct. 12, 1889.

‡ *Engineering*, London, May 29, 1891, p. 642.

§ *Electrical World*, Jan. 25, 1890.

current transformer,* for a three-wire system, has an armature consisting of a double winding of two separate sets of coils, the counterparts of each other in potential energy, and each set having a brush and commutator of its own. The armature windings of this so-called "compensator" are of quite low resistance and designed to give, at its normal speed, an electro-motive force respectively equal to that existing between the side wires and centre wire of the three-wire system. Isolated plant forms of dynamotor transformers are to be seen in the telephone and hotel service electrical work.† And several typical forms of dynamotors have been exhibited at the Frankfort Exhibition last year, details of which may be seen by referring to the current journal reports and correspondence of that period. Respecting the peculiar conditions likely to arise in using the dynamotor in form of an epicyclic mechanism, the field and armature both revolving, Patten has developed a form‡ of dynamo with *revolving* fields and armature. With careful design, construction and management of operations, the dynamotor should range as high as ninety per cent. efficiency as a maximum.

The Kinematics of Electro-magnetic Machinery has been touched upon in the foregoing sections, chiefly with reference to the propriety of including electro-magnetically connected mechanisms with previous typical forms, the mechanical equivalents of dynamotors, and the conception of the electro-magnetic kinematic chain. It remains to be seen whether this portion of the subject may be further developed along existing lines of treatment and classification, as outlined by Willis, Rankine and Reuleaux; or, whether it may not be found to require a peculiarly distinct treatment, owing to the special need of considering the character of the medium, and its own kinematics and dynamics. But, in the present state of our knowledge it is well to guard against too rigidly

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* *Electrical World*, April 16, 1887.

† *Electrical Engineer*, New York, Dec. 23, 1891.

‡ *Electrical World*, Nov. 26, 1887.

adhering to only the kinematical and mechanical conceptions of the ether medium. It is not that the true conception is necessarily otherwise; but, because the electro-magnetic mechanism appears to have many well-known mechanical equivalents. For, almost all the kinematical problems may be solved by electro-magnetic connection, in some cases more readily than by mechanical devices.

The Characteristic Features of the Ether Medium led Maxwell to identify the two phenomena of light and electro-magnetic waves, basing upon this identity his electro-magnetic theory of light. Prof. Henry A. Rowland remarks* that "as yet we cannot conceive of the details of the mechanism which is concerned in the propagation of an electric current. . . . According to our modern theories of physics there must be some medium engaged in the transmission. . . . That medium which is supposed to extend unaltered throughout the whole of space, whose existence is certain, but whose properties we have yet but vaguely conceived; . . . we have finally completely identified the ether which transmits light with the medium which transmits electrical and magnetic disturbances." And, regarding the possibilities bound up in the intensity of the electro-magnetic stresses which are capable of being induced in the ether medium, Mr. A. E. Kennelly states† that they are far in excess of any stress which we can exert without the cohesion of matter. He estimates that one cubic inch of electro-magnetically stressed air, magnetized to a flux density of 5,019 lines per cubic centi metre, and alternated 227 times per second, would store and release energy at an average rate of one horse-power. So that for range of adaptability in meeting the requirements of comparative and constrained motion, as well as for great concentration of energy in the transmission and transformation of energy—the ether medium stands out alone, yet with a rapidly increasing field of application.

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* "On Modern Views with Respect to Electric Currents." *Transactions American Institute of Electrical Engineers.* Vol. vi. No. 7, July, 1889.

† *Transactions American Institute of Electrical Engineers.* Vol. viii. No. 11, Nov., 1891.

BOOK NOTICES.

Systematic Mineralogy, based on a Natural Classification, with a general introduction. By Thomas Sterry Hunt, M.A., LL.D. Author of "Chemical and Geological Essays," "Mineral Physiology and Physiography," "A New Basis for Chemistry," etc. The Scientific Publishing Company, 27 Park Place. New York: 1891.

In order to appreciate what Dr. Hunt has attempted, and what he has accomplished, in this book, we must take a short retrospect of the science at the risk of wearying the learned by repeating what all should know. His own excellent preface states the facts in detail, but they may be summarized as follows:

When the science of mineralogy was created by Werner in the first decade of this century, the science of chemistry was so young that neither its methods nor the instruments of which it could dispose were capable of answering the many questions propounded by the sister science. But there was a whole world of undetermined facts in the physiological and physical properties of those curious entities called minerals, and Werner's quick perception set about establishing them and coördinating them for use in a system.

It is as much an error to suppose that Werner and his followers, Mohs and Breithaupt, Jameson and Shepard, undervalued the aid of chemistry, or believed that the "stuff" was less important than the form and attributes, but they simply could not wait till chemistry grew up, and did as well as they could without her aid. The school-boy need not be told that Werner was one of the great founders of the Freiberg School of Mines, and that his chair has been filled first by Breithaupt, and secondly by its present occupant, Albin Weisbach. The school called by Dr. Hunt the "Natural History" school, or that which depends upon extrinsic characters for bases of classification, is therefore very naturally the Freiberg School of Mineralogy, and nowhere else has the fine scrutiny of these characters been carried to so high a point of perfection. It is this school which has created determinative in contradistinction to analytical mineralogy.

But immediately upon its creation a set of opponents arose who said: "Of what use are your properties of minerals if you do not know the constituent elements of which they are composed?" To which the Wernerite replied: "Of what use is the knowledge of the constituent elements of a mineral, if you do not know what its properties and uses are?" Both were right and both were wrong. It was only a recurrence in this science of the same problems which had perplexed others. Even to-day the paleontologist asks the stratigrapher of what use is a determination of the sequence of rocks if one is ignorant of their ages? and the stratigrapher retorts "How can you know their ages if you are ignorant of which were first deposited?" Of the two contending schools, that of Berzelius, Rose, Phillips, Rammelsberg and Alger, or the chemical, was the least conciliatory, and at the

present day is the dominant one, in spite of the fact that the progress of what is called physics and of chemistry had been great enough to enable any thoughtful mind to perceive that they were mere branches of the same stem, and that no philosophic insight into the laws of the manifestations of matter and force could be complete without the aid of both.

Dr. Hunt saw this clearly many years ago, and outlined the main features of the treatise which we have before us. In completing it he has rendered two distinctive services to the science, which will not be diminished whether or not his system be adopted. The first of them is the plain or irrefutable demonstration that not only is it not expedient, but that it is impossible to consider minerals from less than the two points of view of their ultimate constitution, and their physical characteristics; that in fact, one of them is a function of the other. The second service he has rendered is that of bringing us face to face with the issue of a scientific nomenclature, and compelling us to state whether we are in earnest in accepting the postulates so forcibly insisted upon by Linnæus and Lavoisier, each in his own science, that the names of the various divisions of a classification should not be trivial but should be based upon such inherent qualities of each class as separate it from its fellows of the same grade while including all the individuals of subordinate divisions within it. All naturalists will assent to the justice of the proposition, theoretically, yet in practice it has been neglected in all sciences, and even in chemistry and mineralogy of which Lavoisier and Werner and Breithaupt made it the foundation stone.

The first nine chapters substitute a general introduction to the subject, and treat respectively of (1) The relations of mineralogy. (2) Mineralogical systems. (3) First principles in chemistry. (4) Chemical elements and notation. (5) Specific gravity. (6) Coëfficient of mineral condensation. (7) Theory of solution. (8) Relation of condensation to hardness and insolubility (a very important and original essay). (9) Crystallization.

Chapter X deals with the constitution of mineral species. Chapter XI gives this new classification on four classes, like that of Breithaupt: Metallaceæ, Halidaceæ, Oxydaceæ, and Pyricaustaceæ. Chapter XII lays down the rules for a nomenclature. Chapter XIII recites the list of classes, subclasses, orders, genera and species. Chapters XIV, XV, XVI and XVII are devoted, one to each of the before-named classes. The XVIII and last chapter is a most interesting and valuable treatise on mineral waters. It must be said that while we are glad to have this chapter here or anywhere, it belongs more properly in a treatise on geology, for even if pure water be a mineral yet saline and mineral waters are "rocks" in the geological acceptation of that term.

The volume is well printed and bound, both type and paper are excellent, and but for a few typographical errors such as never would have occurred had the author been always able to subject the proofs to the searching scrutiny that is a second nature to him, the volume would combine every quality which a book-lover would desire. Such errors are the omission of "der" from the title of Rammelsberg's work on the first page of the

preface; the omission of the "p" from "gypsiferous" para. 483, p. 369, etc., etc. But the work is a contribution to science, not the mere collocation of the ideas of numerous dead and living scientists. F.

Boston Society of Natural History: Guides for Science Teaching. No. VIII. Insecta. By Alpheus Hyatt and J. M. Arms. Boston, U. S. A.: D. C. Heath & Co., Publishers. 1890.

Any book from the pen of Mr. Alpheus Hyatt merits the attention and is now to receive the praise of the world. He modestly ascribes the success of this charming little book to Miss J. M. Arms, on the ground that it could not have been accomplished in the absence of aid by her. To whomsoever belongs the praise, it is a book of the class to make science popular, because intelligible to the young mind. After the title page comes the Synopsis, which is really an expanded table of contents. As the first-named author says in the Introduction, which comes after the Synopsis: Insects form the most favorable and are apt to become the favorite means for the teaching of observation in the schools. There are twofold advantages to this selection. (1) It tends to obliterate the repulsion which many children have for insects and "bugs." (2) The study of insects will instruct the beginner to distinguish between the noxious and the harmless insects, and to prevent the indiscriminate slaughter of insects because they are insects. Besides these reasons, the collection of insects is made easy at the warmer seasons of the year, by their number and variety, and their preservation and arrangement is inexpensive and comparatively clean work.

The book is very well and thoroughly illustrated by drawings and tables, thus putting the first steps in entomology within the reach of all.

It is a very encouraging sign to see these well-written and modern books on scientific subjects taking the place of the antiquated text books, many of which contain much that is erroneous, and more that is obsolete, with little that is systematic and clear. F.

Nu English. A proposed simplified English language for home use and for international commerce and travel. By Elias Molee, Ph. B., Minneapolis, Minn. A pamphlet.

This is one of the numerous attempts to introduce a phonetic language, of which our English has been the incitement to the greater number, though by no means all.

French and German have each come in for their share of the supposed saving grace of phonetics. It was proper that a Chicago audience should be informed that after the trifling preliminaries of an agreement between a number of civilized nations to teach Nu English, in addition to their native tongue, to ministers, lawyers, diplomats, physicians and school teachers, the whole of the nations would learn it out of curiosity, and we would present the edifying spectacle of an uni-lingual world. The contractions and combinations are very similar to the German in such words as "word-book," lexicon; "fish-love," ichthyology; "bind-word," conjunction, etc.

We are, however, somewhat appalled to learn that "the greatest economy that I know of at present, which is practical, would be the abolition of the capital letters. They ought to be abolished immediately. I say this as a writer, and type-setter, and ex-teacher," etc.

In response to a supposed objection why the proposed reform does not start in Philadelphia, New York, etc., he replies: "The West is to-day the King of the United States." He modestly adds: "Great ideas have seldom started in great cities, though they (?) are the best for making them (?) known." "Grammatical rules depend more upon natural ingenuity than upon philological erudition ! ! !"

There are a few pages devoted to the Nu English as a means of oratory, in which "Ladies and Gentlemana:" "My friendees and my friendina do first five rula, namely, that all nouna," etc., etc.

This is enough. Due notice of the adoption of this dialect by distant nations will be given. F.

Elektro-Metallurgie. Die Gewinnung der Metalle unter Vermittlung des elektrischen Stromes. Von Dr. W. Borschers. (Mit 90 Text-Abbildungen.) Braunschweig: Harold Bruhn. 1891.

The extraction of certain metals from their ores, and the separation and refining of others from the crude mixtures in which they find their way into the market, have of late been very successfully undertaken and carried out in practice by electric methods. The interesting developments of the past five years which have created such a pronounced revolution in the metallurgy of aluminum and its alloys, have naturally attracted more popular attention than any others; but the electric methods by which lead, copper, silver, gold, etc., are separated and refined are no less interesting to the investigator, and of much greater industrial importance. As the application of the electric method to metallurgy is as yet in its infancy, it is scarcely to be expected that the methods employed, many of which are tentative and empirical, should be found fully treated of in the books—and it happens, therefore, that while the general subject of electro-metallurgy is attracting a large share of attention on the part of enterprising specialists, and while information bearing on the subject is eagerly sought after, the sources of such information are limited both as to number and yield.

We welcome, therefore, any intelligent and conscientious attempt to add to our available literature in this field, and the present work will prove exceedingly useful to all who seek information as to the present state of this art. The only works at the present time accessible to English-speaking students are that of Gore on *Electro-metallurgy*, which is neither so recent nor so complete as this, and that of Richards which treats exclusively of aluminum; and Dr. Borschers' work being more recent than either of these, contains data not to be found in the others. The advances in this field are so rapid and radical that, just at this time, an author has little encouragement to write a book, since it is almost an assured fact that in five years it will be regarded as ancient history. W.

"*Makers of America.*" Robert Fulton. His life and its results. By Robert H. Thurston. New York. Dodd, Mead & Co., Publishers.

It is always an agreeable surprise to have a biographical and historical work from the pen of a master in the science which occupied the life of the subject of his sketch. Indeed no other is capable of treating this class of biography. The book before us is one of the best of this class.

At the outset the author disclaims for his subject the creation *de novo* of an idea, but rather the adaptation of what was known before to practical use, by a combination with other known contrivances. With rare justice, Prof. Thurston mentions the early experiments of William Henry, of Pennsylvania, on the Conestoga Creek, in 1760. He probably originated the idea of the steamboat five years before Fulton was born. Both Fitch and Fulton visited Henry's house. In 1785, Fitch, at a special meeting of the Philosophical Society, was presented to the members. He spoke of Mr. Henry's claim to the first idea of propelling boats by steam.

Fitch lived on the banks of the Neshaminy, in Bucks County, Pa., when he tried the first successful experiments in using steam for the propulsion of boats. He was born in Connecticut. James Rumsey, of New York, also experimented in this direction in 1774. One of Fitch's boats, in April, 1790, made seven miles an hour. Captain Samuel Morey, of Orford, N. H., built a steamboat and ran from Orford to Fairlee, Vt. and back, in 1793. Fulton, the subject of the sketch, was born in Lancaster County, Pa., in 1760, and his career as artist, civil engineer, mechanic and statesman is ably sketched. Especially noteworthy was his invention of a diving boat, which was successful even when compared with modern apparatus of the time. He also suggested the screw propeller and devised submarine ordnance for firing through the water at the submerged part of a vessel's hull. He devised a twin-screw steamer in 1805. The book is well and fully illustrated, and is as extremely interesting as a narrative as it is valuable as a collection of well sifted historical data.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 17, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 17, 1892.

Mr. JOS. M. WILSON, President, in the chair.

Present, sixty-eight members and fourteen visitors.

Additions to membership since last report, eight.

The Secretary reported the resignations of Messrs. F. Lynwood Garrison and Otto C. Wolf from the Committee on Science and the Arts. The vacancies were thereupon filled by the election of Mr. Frank P. Brown for the unexpired term of Mr. Garrison, and Mr. Henry F. Colvin for the unexpired term of Mr. Wolf.

Mr. Carl Hering, delegate of the Institute to the Frankfort Electrical Exhibition, described some of the principal features of the Exhibition. (Mr. Hering's report will shortly appear in the *Journal*.)

Mr. James M. Dodge gave an oral account of the subject of coal storage, and illustrated, by means of a series of lantern slides, the substitution of the inefficient and comparatively expensive methods of the past by the vastly more efficient mechanical methods of storing and re-loading this product, which are now very generally used by the large companies engaged in the transportation of coal.

The Secretary's report was devoted principally to an account of the recent developments in the application of electricity to the welding and forging and shaping of metals.

Mr. John Carbutt described certain recent improvements in photographic methods, and exhibited some remarkable panoramic pictures forty-eight inches in length, made upon a curved celluloid plate; also several specimens of photographs of objects taken at a distance of several thousand feet by means of a peculiar combination of lenses devised for the purpose by Dr. Miethe, a German expert, and adapted to be used in a camera of ordinary size. A picture of the same subject and from the same standpoint, made, respectively, with an ordinary lens and the tele-photo lens of Dr. Mitehe, were shown side by side on the screen, and exhibited a surprising difference; the latter showing distinctly details that were quite invisible upon the former.

Adjourned.

WM. H. WAHL, *Secretary*.

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Taken from a distance of 250 m with an ordinary Dallmeyer symmetrical lens smallest stop, Exposure 1/5 sec.

From the same standpoint
Münchner Bürgerbräu
taken from a distance of 350 m. with the Miethe
new telephotographic lens. Combination 1:28 cm.
Exposure 05 sec.

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